West Virginia University Libraries
Treatise on dental caries. hioc
3 0802 001029566 7

KS
DO NOT CIRCULATE

RECEIVED

NOV 28 1958

WEST VIRGINIA UNIVERSITY
MEDICAL CENTER LIBRARY

Digitized by the Internet Archive
in 2012 with funding from
LYRASIS Members and Sloan Foundation

http://www.archive.org/details/treatiseondental00magi

# TREATISE

ON

# DENTAL CARIES.

## EXPERIMENTAL AND THERAPEUTIC INVESTIGATIONS

BY

DR. E. MAGITOT,

LAUREATE OF THE INSTITUTE OF FRANCE, OF THE FACULTY AND THE ACADEMY OF MEDICINE OF PARIS; MEMBER OF THE SOCIETIES OF SURGERY AND OF BIOLOGY; SECRETARY GENERAL OF THE SOCIETY OF ANTHROPOLOGY OF PARIS; CORRESPONDENT OF THE ROYAL ACADEMY OF MEDICINE OF BELGIUM, OF THE ODONTOLOGICAL SOCIETY OF LONDON, OF THE AMERICAN DENTAL ASSOCIATION, AND CHEVALIER OF THE LEGION OF HONOR.

*CROWNED BY THE ACADEMY OF MEDICINE.*

"*La médecine scientifique ne peut se constituer que par la voie expérimentale.*"
CL. BERNARD, Introduction to the Study of Experimental Medicine.

TRANSLATED BY

THOMAS H. CHANDLER, D.M.D.,

PROF. OF MECHANICAL DENTISTRY, AND DEAN OF THE DENTAL SCHOOL OF HARVARD UNIVERSITY.

BOSTON:
HOUGHTON, OSGOOD AND COMPANY.
The Riverside Press, Cambridge.
1878.

OLD BOOKS

M34
1878

Copyright, 1878,
By THOMAS H. CHANDLER.

*All rights reserved.*

RIVERSIDE, CAMBRIDGE:
STEREOTYPED AND PRINTED BY
H. O. HOUGHTON AND COMPANY.

# TRANSLATOR'S PREFACE.

Dr. Magitot is well known in England and on the continent of Europe, as a laborious investigator and writer on dental subjects; but to this country his fame seems not to have extended, chiefly, it is inferred, from the fact that his works are written in a foreign tongue, and that those most interested in his chosen themes, busy with their calling, have not the time to devote to translating. The subject of this work, however, Dental Caries, is one possessing more than a special interest, and, although ostensibly appealing to a single body of practitioners, has light for all.

As far as is known to the translator, no writer has investigated this subject so systematically and thoroughly as Dr. Magitot, and his conclusions are therefore grounded on something more substantial than the speculations which have heretofore formed the basis of our "knowledge" of this malady. His experiments are definitely stated and can easily be repeated by any one who doubts their results, while the conclusions logically drawn therefrom must be admitted if we admit his premises. In the matter of the treatment of Dental Caries the translator has felt compelled to differ in some few regards from his

author, as will be seen by the appended notes. Although the principles of the treatment may be well grounded and as well stated, yet the employment of drugs and the perception of their action must always be more or less a matter of experiment and empiricism, and each must draw his conclusions mainly from his own observations.

The plates at the end of the volume, and the wood-cuts illustrating the text in the body of the work, are the same as were used in the original edition, and the chart of the geographical distribution of Dental Caries throughout the Departments of France, which is the property of Dr. Magitot, has been inserted with his sanction. An alphabetical index has also been added, which, it is believed, will add greatly to the value of the work by promoting ease of reference.

The writer has been sufficiently impressed with the value of the work as a whole to devote the best part of his leisure for nearly two years to putting it into an English dress, that his fellow-practitioners may the more easily share its advantages with him. Whatever faults of diction or mistakes of meaning are found must be charged to the translator, as the whole work has been done by him without advice or assistance of any kind. Such as it is, he dedicates it to the dental profession, hoping it will contribute to the advance of Dental Science in this country, and afford as much profit to its readers as he has derived pleasure from the more arduous work of translating.

THOMAS H. CHANDLER.

*July*, 1878.

# TABLE OF CONTENTS.

PRELIMINARY AND HISTORICAL . . . . 1

## CHAPTER I.

### PATHOLOGIC ANATOMY.

A. Anatomical Résumé of the Structure of the Dental Organ . . . . . 11
§ 1. Hard Portions of the Teeth . . . . . 11
§ 2. Soft Parts of the Teeth. . . . . 24
B. Anatomic Lesions of Caries . . . . . 28
§ 1. Lesions of the First Period . . . . . 28
§ 2. Lesions of the Second Period . . . . . 34
§ 3. Lesions of the Third Period . . . . . 45

## CHAPTER II.

### ETIOLOGY AND EXPERIMENTS.

§ 1. Predisposing Anatomical Conditions . . . 50
A. Congenital Anatomic Conditions. Chart of the Geographic Distribution of Dental Caries . . . 50
B. Acquired Anatomic Conditions . . . . . 82
§ 2. Of the Saliva and its Modifications . . . 85
A. Normal Saliva . . . . . 86
B. Accidental and Pathologic Modifications of the Saliva 104
1. Accidental Modifications . . . . . 104
2. Morbid Modifications . . . . . 114
§ 3. Direct Experiments; Experimental Production of Artificial Caries . . . . . 121
A. Experiments in Saliva . . . . . 122
B. Laboratory Experiments . . . . . 127
§ 4. Mechanism of the Production of Dental Caries 157

## CHAPTER III.

### PROGRESS, SYMPTOMATOLOGY, COMPLICATIONS.

PROGRESS, SYMPTOMS, AND SIGNS OF CARIES . . . . 167
§ 1. First Period . . . . . 167
§ 2. Second Period . . . . . 173
§ 3. Third Period . . . . . 178
COMPLICATIONS OF CARIES . . . . . 185

## CHAPTER IV.

### NOSOLOGY AND DIAGNOSIS.

NOSOLOGY . . . . . 190
DIAGNOSIS . . . . . 193

## CHAPTER V.

### TREATMENT.

A. PREVENTIVE TREATMENT . . . . . 205
B. CURATIVE TREATMENT . . . . . 212
§ 1. Treatment of the First Period . . . . . 213
Observations . . . . . 216
§ 2. Treatment of the Second Period . . . . . 218
Observations . . . . . 224
§ 3. Treatment of the Third Period . . . . . 227
Observations . . . . . 249

GENERAL CONCLUSIONS . . . . . 260
EXPLANATION OF THE PLATES . . . . . 265

# TREATISE

ON

# DENTAL CARIES.

## PRELIMINARY AND HISTORICAL.

The Dental Organ, separately considered, may be affected by numerous maladies which are for the most part very little understood. Among them, that designated by the term *Caries* is certainly the most frequent, and also one of the gravest; for, left to itself, it may occasion immediately pain more or less acute, and remotely the destruction of a part or all of the teeth; complications in the mouth and its neighborhood, sometimes serious; disturbances of the digestive functions and of the general health. The nature of this malady, which has been discussed without arriving at a clear understanding of it, is sufficiently complex. Its elucidation presupposes, in fact, first an exact knowledge of the normal constitution of the dental tissues and of their functional phenomena, a knowledge upon which depends the study of the pathologic anatomy and physiology of the malady. It comprehends next the investigation of the conditions under which the malady is produced and developed. This etiological examination admits of several orders of inquiries: 1st. The study of the general anatomical predispositions,

vices of conformation, external and internal defects, etc. 2d. The determination of the destructive agent, of its mode of formation, of its characteristics, of everything leading to an exact idea of the intimate nature of the lesion. 3d. The statement of the mode of production of dental caries. This work will, moreover, comprehend the study of the progress of the disease, a progress so variable, slow or rapid, depending upon diverse influences and a certain vital resistance of the organ itself, which we will determine; at times capable of a temporary suspension, followed after a longer or shorter period by a new recrudescence; at other times experiencing a complete and definitive arrest, resulting in a veritable spontaneous cure. Finally, after a symptomatological examination of the characteristics and diverse phenomena of the malady, according to diagnostic indications and complications, we will undertake a description of great practical importance, the *treatment;* that is to say, the study of the methods of cure, and the description of the therapeutic measures applicable to the different degrees and forms of the lesion. These measures, in a great majority of cases, permit, as we will show, our arriving by a rational and rigorous method at its complete and definitive cure.[1]

These investigations have led us to accurate and precise data as to the character and the nature, which have been so disputed, of dental caries, while, at the same time, they permit us to formulate a rational definition of it.

Dental caries is characterized by a progressive soften-

[1] By the cure of dental caries we mean the complete and definitive cessation of the accidents which accompany it, together with conservation of the organ and the reëstablishment of its uses.

ing and continuous destruction of the hard tissues of the teeth, advancing constantly from the exterior to the interior of the crown, and causing the gradual disappearance of a more or less extensive portion, even to the whole of the organ.

This definition necessitates some explanations. It is evident on the face that no analogy can be admitted to exist between caries of the teeth and that of the bones, any more than the anatomical comparison of these two orders of tissues is admissible. Modern research upon the texture and internal structure of these organs has clearly established this distinction, which is now an acquired fact to science.

The tooth, a special organ in the animal series by its constitution, its position, and its uses, although subject to the general laws of the organization, may present a variety of lesions of a nature peculiar to itself, by reason of its special character. Situated on the surface of the body as a dependency upon the tegumentary system, and classed in the order of its products, it is exposed in man, in the cavity of the mouth, to influences of a physical or chemical nature, amongst various reactions of which this cavity is the laboratory, and, as we will show, it is to a change of this kind that caries owes its birth.

We believe that the tooth, in spite of its incontestable vitality and nutritive movement, undergoes, in the malady of which we are treating, a veritable chemical alteration which dissociates and destroys its elements, not indeed passively and unresisted, but, from this very vitality, eliciting special phenomena of resistance. These phenomena, without effecting the reparation of losses of substance already undergone, are nevertheless, by a series of spontaneous modifications, a veritable contest which the econ-

omy sustains, able to bring about a temporary or permanent arrest of the disease. It is this contest, often impotent, which points to the natural and logical way to be followed by the intervention of art, whose rôle will often consist in the provocation or imitation of these spontaneous resistances. Yet, if caries is due exclusively to a chemical change in the dental substance, the mechanism of this change should be uniform. And, in fact, caries, notwithstanding the variety of its causes, recognizes but one sole agent, the saliva, not indeed the secretion of this or that gland in particular, but the mixed buccal fluid, composed of substances found in the mouth either spontaneously developed or accidentally introduced, and acting destructively upon the teeth. This doctrine again conducts us to this consequence, that caries of the teeth, looked at as a purely chemical change, ought to be able to be artificially reproduced, as in fact our experiments will show to be the case, when we reproduce or imitate the conditions of alteration presented by the mouth itself.

Entirely abandoned by the majority of physicians, who have always neglected this kind of investigation, the study of this malady and particularly its treatment have, with most of the remaining problems of general odontology, been handed over to the blindest empiricism. Therefore it has seemed to us useful, while recognizing the work of a few authors, to submit the sufficiently complex subject of dental caries to a rigorous and scientific investigation. Such is the object of this work.

For the first documents referring to dental caries we must go back to the very origin of the traditions which have come down to us. Every age, every people have been afflicted with this malady, and all have brought to

it attention and research on a level with their general information in natural history and medicine. We find evidence of the existence of dental caries in the very earliest ages of humanity. The fossil jaw found at Abbeville by Boucher de Perthes contained a tooth extensively carious.[1] Other teeth discovered among the bones found in the caverns of the prehistoric epoch likewise show evidence of caries.[2] We remark that this affection appears at this period to have been much less frequent than today, for it is found in only ten or twelve teeth in a thousand, that is, about one per cent.

Moreover, man is not the only mammifer affected by this malady. The domestic animals not unfrequently suffer from it; and, with them, it appears in connection with certain conditions of alimentation to which they are subjected in a state of domestication, for the wild species are ordinarily exempt from it. Yet we must except certain species the most akin to man, the anthropomorph apes, chimpanzees, and gorillas, among which caries has been observed,[3] and we may readily explain the fact by the analogies of conformation of their dental system with that of man, and more than all by the use of fruits, of which their alimentation is almost exclusively composed.

After the Egyptians and the Hebrews, among whom tradition permits the recognition of the existence of the disease and of the various methods by which they opposed it, such as cauterizing the temples[4] with fire, the

[1] *Comptes Rendus de l'Académie des Sciences,* 1863, vol. lvi., p. 779.

[2] See Garrigou, *Bulletins de la Société d'Anthropologie de Paris,* vol. v., p. 926.

[3] See Du Chaillu, *Voyage en Afrique Centrale,* 1862, p. 299.

[4] Prosper Alpin, *De Medicina Ægyptiorum.*

first observations at all precise go back to the Greek epoch: Cicero mentions that the third Esculapius was the inventor of an instrument for the extraction of carious teeth, an instrument which, according to Erasistratos, cited by Cœlius Aurelianus, was of lead, which would seem to show that it was applicable rather to loosened teeth than to teeth properly called carious. The Hippocratic books contain documents more precise, and, above all, more authentic upon this malady. In them; mention is made of cauterization as a means of cure of odontalgia, except that this was not applied to the caries itself, but, in the Egyptian and Indian method, to various parts of the body, the ear, the shoulder, etc., as a counter-irritant. In the interval reaching from Hippocrates to Celsus, the facts relating to dental caries are few and obscure. Diocles, pupil of the school of Cos and firm opponent of the extraction of the teeth, proposed, for quieting the pains from caries, a mixture, of which Galen has given us the formula.

Heraclides and Herophiles, of the school of Tarentum, only mention that cases of extraction have been the cause of death. In the age of Augustus, we find in Damocrates, Scribonius Largus, and Strabo reference to some compositions intended to relieve pains in the teeth, but especially receipts and formulæ of cosmetics used for the care of the mouth.

Celsus,[1] usually so good an observer, gives no description of the malady, nor indicates even the character of the pain it occasions. He confines himself to offering a series of receipts and compounds intended to be used either in the carious tooth or in the mouth. These are usually mixtures of resinous or aromatic substances with

[1] Lib. vi., ix.

pepper, opium, saffron, sulphur, etc. He advises also external emollient and epispastic applications, and, above all, insists upon general treatment: diet, purgatives, abstention from or use of certain kinds of food, etc. As to the plugging of teeth, of which the idea has been attributed to Celsus, it was already practiced in the time of the Greeks, as the tombs of this epoch show, where are found carious teeth whose cavities have been filled with gold in leaves.[1] From the Roman epoch to the Renaissance, a period during which knowledge of general medicine was lost in the common darkness, there is nothing worthy of note upon dental caries.

In the sixteenth century we have the first work written specially upon the teeth. It is by a disciple of the surgical school of Strasbourg, and appeared in 1548. Of this work there has come down to us but a simple mention of Sprengel.[2] From this time, treatises upon medicine or surgery, whether general or specially of the art of the dentist, have regarded caries in a manner varying with the ideas generally held of the nature of the dental organ itself. Thus, A. Paré,[3] who regards them as bones, makes no difference between this disease and osseous caries properly so called.

It is only since the beginning of this century that the labors of anatomists have made known the composition and nature of the teeth, determining their physiology and their special rôle in the animal economy. Recent investigations, aided by the microscope, have more precisely determined the texture and internal structure of

[1] This statement is doubted. No authorities are found which warrant it. Skulls have been found with the teeth gilded, which has been mistaken for gold fillings. — TRANSLATOR.

[2] *Histoire des Principales Opérations de la Chirurgie,* vol. viii., p. 253.

[3] Edition Malgaigne, vol. i., p. 231 ; vol. ii., p. 443, and subsequent pages.

these organs, and the results are of great value in the study and for the understanding of the different lesions of which the tooth is the seat.

The opinions now entertained of dental caries may be summed in three doctrines which we will present and discuss briefly, and to which we shall recur again in the course of this work. The first holds that dental caries is an affection of an exclusively vital or organic nature, at times inflammatory, as Fauchard and Jourdain believed; at times produced by gangrene or mortification of the dental tissue, as thought Hunter, Bell, Cuvier, Duval, Linderer, Meekel, Fox, etc. In accordance with this opinion, caries is a spontaneous affection, coming on without our being able to determine its precise cause, and, like all inflammations and gangrenes, subject to the influence of general or local causes. We will not discuss this opinion at length. It suffices to say, so far as concerns the idea of *inflammation*, that the hard tissues of the teeth being, both in their normal and pathologic condition, destitute of vessels, this morbid phenomenon cannot be produced. As for the idea of *gangrene*, *necrosis*, or of any other cause of destruction of an organic nature, if at the first sight of a case of caries this appears probable, it should be considered that there can be no reason why such an alteration should proceed always from the exterior to the interior of the organ, and also that there should be observed cases of internal caries. Now, no example of this kind has been rigorously proved, every cavity of caries having an external orifice whose position corresponds exactly to the place of the origin of the disease. To this argument, which should be conclusive, we will add that this theory cannot explain the caries of corresponding teeth on both sides of the jaw, at the same

time and place; the production of artificial caries, as our experiments have shown, and the mechanism of its cure by the different methods of isolation and plugging.

The second theory considers caries as a purely chemical lesion, which attacks the tooth in a manner absolutely passive, and results from the presence of an acid agent in the month. This doctrine has for its advocates a few modern authors, — Tomes, Harris, etc. Developed already, with some care, by Regnart,[1] in a pamphlet which excited a lively discussion, for want of exact observations and vigorous experiment it could not be clearly established. It is this theory, whose principles we hold, which we have resolved to develop and to subject to a minute investigation, and to the test of direct experiment.

The third theory, which nowadays M. Oudet almost alone defends, asserts the existence of two kinds of caries, one resulting from an internal cause, either local or general, *internal caries;* another of external origin, which receives the name of chemical change, properly so called. We will not discuss this theory, whose first part falls under the arguments already given, and whose second point is included in the doctrine just mentioned. Moreover, caries is *one*, and an identical lesion cannot be produced by causes so differing.

Our work will be divided as follows, in accordance with the method generally followed in nosographic descriptions.

*First.* Pathologic anatomy, or study of the lesions of dental caries, preceded by a rapid survey of the normal anatomy of the organ.

[1] *Recherches sur la Carie Dentaire.* (*Gazette des Hôpitaux ou Lancette Française,* 1838.)

*Second.* Etiology and experiments.

*Third.* Progress, symptomatology, complications.

*Fourth.* Nosology and diagnosis.

*Fifth.* Treatment.

*Sixth.* Finally, after a short *résumé*, we shall give, in the form of aphorisms, a series of conclusions resulting from the whole of our study.

# CHAPTER I.

## PATHOLOGIC ANATOMY.

### (*a.*) ANATOMICAL RÉSUMÉ OF THE STRUCTURE OF THE DENTAL ORGAN.[1]

In the histologic study of the adult teeth we will make two divisions: (1) The hard parts; dentine, enamel, cement; (2) the soft parts; pulp or dental germ, and the periosteum or alveolo-dental membrane.

#### (1.) *Hard Portions of the Teeth.*

A. Dentine or Ivory. — The dentine or ivory represents the most considerable portion of the dental organ. Upon this are molded the two other tissues, the enamel covering the crown, the cement inclosing the root. It follows, therefore, from this disposition, that it appears nowhere on the exterior. Nevertheless, it has been asserted that the ivory is uncovered at one point, namely, the neck of the tooth, but modern inquiry has established that at this point the cement is prolonged some millimetres beyond the termination of the enamel.

The dentine in a freshly extracted tooth is a yellowish, semi-transparent substance; when dried it is a brilliant and pearly white. Its density is intermediate between

[1] See for the development of these anatomic ideas our special articles: *On the Development and Structure of the Human Teeth*, 1857, J. B. Baillière, p. 83; *Genesis and Evolution of the Dental Follicles*, by Ch. Robin and E. Magitot; *Journal de Physiologie*, 1860, p. 671.

those of cement and enamel, and moreover varies with the age; so, relatively deficient in the infant and the adult, it becomes very considerable in the aged whose teeth are hard and brittle. The external face of the dentine is covered by the enamel in the crown and by the cement in the root. In the crown it is marked with minute, concave, hexagonal depressions noticed by Owen and Huxley, and intended to receive the extremities of the enamel prisms, giving it a quite remarkable reticulated aspect. In the root the external surface of the ivory is uneven and rugose, covered with crevices filled with cement.

The internal face corresponds to the pulp cavity and to the dental canals arising from it. It is molded exactly to the parts it covers, and presents the innumerable orifices of the open canalicules at its inner surface towards the pulp.

The dental cavity which contains the pulp, as well as the pulp itself, has the same configuration, but smaller, as the tooth itself at its exterior. This cavity, very large in the infant when the pulp is voluminous, gradually diminishes with age, a fact which permits us to say that increase of volume of the tooth is continuous, not indeed, it is true, as with the rodents, in which this organ, worn away by mastication, as regularly increases in length, and without cessation is pushed forward from its alveolus. This increase in the human tooth is confined to the cavity of the pulp, whose capacity diminishes little by little, finally disappearing almost entirely before the incessant production of ivory. The ivory is composed of a *fundamental substance* permeated by a multitude of minute canalicules.

The fundamental substance appears completely homo-

geneous and very finely granulous when highly magnified. Subjected to prolonged maceration in hydrochloric acid, it may be entirely separated into large fibres running in the direction of the canalicules. These large fibres may themselves be separated into smaller ones, a fact which has led some authors to believe that the tooth has really a fibrous structure (Nasmyth, Raschkow, Oudet). But it is easy to see that these fibres have a very irregular arrangement and that they are purely artificial. They result indeed from the disposition of the tubules, which, standing parallel to one another, intercept portions of dentine to which decalcification gives the appearance of fibres. The fundamental substance is distributed throughout every portion of the ivory in variable proportions; therefore, in the external parts underlying the enamel and the cement, it is much more abundant than in the vicinage of the dental cavity where the canalicules are extremely crowded.

The whole mass of the ivory presents an appearance as if stratified, indicated in a vertical section by curved lines parallel with each other and with the exterior contour of the crown. These lines, called by Owen lines of contour, are generally quite close to one another, and their intervals are regular. It is also at the surface of these lines that we observe on the same sections the profile of dentinal globules and interglobular spaces, when they exist. These globules and the spaces they inclose are not equally marked in different teeth, for they are progressively effaced by age without ever entirely disappearing; therefore they may be discovered even in the teeth of the aged under the form of curved lines quite faint and very fine.

The dentine is bounded throughout its whole external

surface by a continuous layer of dark granulations very numerous and of very various form. This granular layer, subjacent to the enamel and cement, was taken by Retzius and J. Müller for a mass of bony corpuscles in which terminated the canalicules. But an attentive examination shows that, although the granulations are continuous with the terminal extremities of the canalicules, we cannot compare them to osseous corpuscles, but that they should rather be regarded as minute pits sunk in the thickness of the ivory, at its exterior limit, to aid the communications between the tubules which permeate this tissue. Therefore we have proposed to call this granular layer *the anastomotic plexus* of the dental canalicules, meant to permit a free course to the fluid of imbibition and thus to favor the organic movement. What proves this is that the aspect under which these cavities present themselves is the same as that of the canalicules. Thus when these latter are filled with a liquid which renders them white and transparent the little cavities are white and transparent, and they become dark and opaque when the tubules, filled with air, show the same color. Moreover it is easy, by changing the focus of the microscope, to see that the two communicate freely with each other. This granular layer has long been noticed. This it is that represents the vestige of membrane between the ivory and the enamel, which Cuvier thought he had discovered.

The dental canalicules, discovered in 1678 by Leeuwenhoeck, are microscopic tubules penetrating the thickness of the ivory. They open into the dental cavity by an orifice in immediate contact with the surface of the pulp, and radiate from this point to the exterior of the tooth, showing in their course a great number of more or less

marked sinuosities. Besides these partial sinuosities, there are seen also general curves belonging to a great number of the tubules which throughout their length undergo two or three great inflections.

The calibre of the tubules differs with the different points of their length. At their orifice, in the cavity of the pulp, it may reach .005 mm. but the mean diameter is from .0015 mm. to .002 mm. In the terminal extremities of the canalicules, the calibre sometimes becomes so small that the final ramifications cannot be perceived. The extreme tenuity of these tubules might in strictness serve as an argument against the opinion held by some authors who wish to liken them to the Haversian canals of the osseous tissue. It may easily be seen that the mean diameter of the blood globules, .006, is always greater than that of these tubules.

The number of the canalicules is often so great that their walls come almost in contact. At their origin at the surface of the pulp they send out lateral ramifications which ordinarily circumscribe the bases of the cellules or of the masses of calcified dentine which they represent; subsequently they undergo a first bifurcation, whose branches soon subdivide in their turn a great number of times, so that one primitive trunk may, according to Kölliker, give origin to as many as sixteen canalicules. These then proceed parallel, without any new bifurcations for a certain distance, but when they come near the external surface of the ivory they divide anew into a multitude of branches or twigs terminating in the grand anastomotic plexus of which we have previously spoken. The reciprocal anastomoses of the canalicules take place in different ways: ordinarily they are lateral and oblique, sometimes directly transverse, and finally

some are disposed in curves which return to the main branch.

Each canalicule in its principal trunk, its secondary branches, and its anastomotic cavities is clothed with a wall proper, whose existence, often doubted, is clearly revealed by the examination of thin sections of dentine subjected to the action of a diluted acid. These walls, composed of a resisting tissue, are then isolated from the fundamental substance of the ivory, and float in the preparation as dark filaments. They are composed of a transparent, homogeneous matter without granulations or striæ, with no trace of organization in a word, and containing neither vessels nor nerves.

During life the dental canalicules inclose a transparent, colorless fluid, containing, according to Hannover, calcareous matter in solution. This fluid is probably intended to effect the organic movement in the internal portions of the tooth; this is at least the logical conclusion, although no experiment gives us any direct demonstration of the fact. It has indeed been held by some that this liquid possesses a continuous movement throughout the whole substance of the ivory, but other authors have denied this circulation. As for ourselves, we are much disposed to believe that this liquid, charged with materials of nutrition, bathes the canalicules through their whole extent, and accomplishes the double movement of assimilation and dis-assimilation, thus setting up a certain exchange, slow indeed, but yet aided by the very disposition of the canalicules and their multitudinous anastomoses. The teeth contain no trace of either vessels or nerves, and as for the other cavities which we sometimes find in the body of the dentine, they appear to result from arrested development, or from imperfect

calcification, therefore they must be considered only as faults of conformation. These are without doubt the cavities, always minute, already remarked by Czermak and Hannover, and of which we ourselves possess a remarkable example in our collection, which have been regarded by Tomes as Haversian canals and by other authors as internal caries. For a long time there has been attributed to the ivory a sensibility of its own, an opinion still held by many, even in the admitted absence of nerve branches, and supported by the fact that the teeth vividly perceive the impressions of temperature, of acids, etc., and distinguish the physical qualities of bodies submitted to their contact, such as grains of sand, and hairs.

This tactile sensibility in fact does not belong to the ivory, and must be attributed to the extreme facility with which this substance receives the least vibrations, the slightest disturbances which are given to it by external influences, and transmits them to the pulp, whose tissue, extremely rich in nerves, fills exactly its solid shell and thus perceives the smallest impressions communicated to it; moreover, it varies in intensity in different portions of the dentinal tissue. In the vicinage of the pulp it is naturally very vivid, in consequence of the ready transmission of the impressions received; it diminishes progressively as we go from this point, to become again excessive at the border of the gray layer, or seat of the anastomotic cavities. This peculiarity permits us to attribute to the wall proper, which envelops the canalicules and their anastomoses, some part in the production of the phenomenon. This membrane, covering in fact a canal permeable through the whole extent of the tissue, is more susceptible than the ivory itself of

transmitting, by means of motion or vibration, external influences, and there, at the point where this membrane is most expanded, this sensibility is found to be most acute.

B. Of the Enamel. — The *enamel*, or vitreous substance, clothes with a continuous layer the whole external surface of the crown. This layer is of variable thickness; considerable at the masticating surface, and especially at the points of the cusps, it becomes thinner as we go towards the root, terminating at the neck in a very thin edge. The enamel is a milky white substance of various shades according to the subject; it is diaphanous, and its homogeneous nature, joined to its chemical constitution extremely rich in calcareous materials, gives it such hardness that it resists the file and strikes fire against steel (Nasmyth). The intimate union of the enamel with the ivory, the closely joined disposition of the elements that compose it, and its very great resistance to chemical agents constitute it a powerful means of protection for the crown. Nevertheless this substance may disappear little by little by the wear of mastication, and leave the ivory of the crown exposed. Yet this circumstance has not the injurious influence which might be supposed, for it takes place physiologically only at an advanced age, when the dentine, having acquired a considerable hardness of its own, can resist alone the influences to which it is subjected.

The layer of enamel surrounding the crown is composed of an infinite number of rods, prismatic by reciprocal pressure, whose length is just equal to the thickness of the tissue at the corresponding point, and intimately united without the interposition of any other substance.

The enamel fits itself closely, by the inequalities of its inner surface, to that of the dentine pitted as we have seen with minute depressions to receive the parts which meet it; its external face, likewise rugose, is covered with a thin amorphous pellicle first described by Nasmyth,[1] under the name of *persistent capsule*, and to which authors are forced to attribute a rôle and an origin anterior to the development of the tooth. This pellicle, called by Kölliker *enamel cuticle*, is a thin membrane which can be separated from the surface of the enamel only by means of acids. It is transparent and slightly granular: its mean thickness is .001 mm. If we give credence to this author, it is unassailable by all chemical agents, possesses great powers of resistance, and therefore affords to the tooth an excellent means of protection. Boiled in a solution of potash or soda it swells slightly without being broken up, and the alkali used for this purpose gives with hydrochloric acid a slight precipitate soluble in an excess of acid. This enamel cuticle seems composed of an organic azotized material, impregnated with calcareous salts, for its combustion yields an ammoniacal odor and leaves a residue of alkaline ash.

The direction taken by the enamel prisms or columns is generally perpendicular to the surface of the dentine upon which they rest. At the points where this surface

[1] This *cuticle*, which has not yet been noticed in France by any anatomist, is very easily isolated. We prepare for this purpose a thin layer from the crown of a tooth freshly erupted, or just previous to its eruption; this is ground down thin, taking care to leave intact the outer surface of the enamel. This is then placed between two plates of glass moistened with a drop of water upon the field of a microscope; a drop or two of hydrochloric acid is then added, and soon a thin membrane will be seen to separate from the edge of the enamel, driven off by the bubbles of gas which issue on every side.

is convex the prisms lose their parallel arrangement, and diverge towards the exterior of the enamel. This circumstance gives occasion, towards the peripheric extremities of these prisms, for separations filled by minute interstitial pyramidal columns, which consequently do not reach the surface of the ivory. In the concave surfaces, on the contrary, the columns springing from opposite sides of the concavity form angles by their union, or meet by their free ends. In these two cases the junction of the prisms is often imperfect, and at their points of meeting they undergo changes of direction, from which result irregular, confused masses, at times forming spirals. These faults of conformation, frequent in the concavity of the crowns of the molars, often form at the surface of the enamel a fissure, at the bottom of which the ivory is exposed.

Throughout their length the columns of the enamel undergo parallel undulations, sometimes regular, whence result general curvatures; at other times irregular, giving rise to spirals or zigzags. These peculiarities, however, present themselves only at the points where the enamel is of great thickness, for, where the thinness is such that a single column measures the whole thickness of the enamel layer, the prisms are regularly parallel. The junctions of the columns of enamel are often imperfect, so much so that at times there are found between them in malformed teeth numerous lacunæ, particularly near the surface of the ivory. At this last point they ordinarily have the form of elongated clefts, which may sometimes pass the bounds of the enamel and penetrate a short distance into the ivory, where authors have held that they receive the terminal ramifications of the canalicules, of which some have even considered them

expansions. Other lacunæ are also found in the midst of the bundles of prisms, but we have never observed the cavities which Tomes has remarked in the interior of the prisms themselves. These various faults of conformation have the serious inconvenience of predisposing the teeth to fracture and to caries.

The enamel prisms present transverse striæ reciprocally parallel and distant from .002 mm. to .004 mm. This disposition, which authors have compared to the striation of the muscular fibres of animals, appears to us to be the effect of a peculiar modification of the organization of these elements.

The enamel, once developed, undergoes only an extremely slow organic change; but this movement exists; we cannot ignore the alterations in the density and coloration of which this tissue is the seat during life, nor the fragility it acquires when the tooth is separated from the economy, and therefore dead.

C. Of the Cement. — The cement, the least considerable portion of the dental organ, is a veritable osseous substance. In the human teeth it covers the whole surface of the roots. Beginning at the neck by a thin border which is prolonged slightly beyond the edge of the enamel, it becomes thickened, little by little, in proportion as it approaches the tip of the root, where its thickness attains at times from three to four millimeters. Its external aspect is very like that of bone; it is yellowish and opaque, of a density near that of the osseous tissue, and inferior to that of dentine. Applied closely to the outer surface of the latter, it fills exactly all its irregularities, so that the line of demarkation between the two tissues often becomes inappreciable. Its external surface, cov-

ered with minute nodes, is clothed by the alveolo-dental membrane, which here performs the office of a true periosteum and whose vessels communicate with the cemental tissue.

The layer of cement is developed together with the roots it covers, and presents a continuous increase of volume. Thus, very slight at the outset of its formation, its thickness increases with age and becomes quite considerable in old age, a circumstance which explains how some teeth of old persons are kept in their sockets by means of the layer of cement that surrounds them and in spite of the complete atrophy of the central pulp.

In like manner as the bones, the cement is composed of a fundamental substance and of osseous cavities (osseous corpuscles of Purkinje, osteoplasts of Robin). As for the Haversian canals, they are never found in man except when the cement has acquired a certain thickness, at the ends of the roots, for example, and chiefly in the hypertrophied masses known under the name of exostoses, affections very common in man.

The fundamental substance of the cement is homogeneous, or finely granular and diaphanous. In the neighborhood of the neck, where it contains no osteoplasts, it is thin, translucent, and friable ; here, also, it is often found with striæ, fissures, etc. In the thicker portions it is at times disposed in stratified layers, common in the osseous tissue, and in these cases is likewise to be observed the presence of the Haversian canals, whose vacuity serves as the common centre of the stratifications of the osseous substance.

The osseous corpuscles, or osteoplasts, are commonly disposed in the interior of the cement in a very irregular fashion. We need not then consider, with Kölliker, their

precision of form and the various characteristics which are found to mark them in the bones. Their number is always proportionate to the thickness of the layer of cement. Their direction, according to Hannover, is such that their greatest diameter is perpendicular to the axis of the tooth ; whilst according to Kölliker, the diameter is parallel to this axis. As for ourselves, we have found no regular arrangement of them in the thickness of the cement. It is only at those points where we find an Haversian canal that the osteoplasts take a direction parallel to the contour of the stratified laminæ, and show a somewhat regular form and arrangement.

The ramified canalicules of the osteoplasts most frequently partake of the irregularity of the cavity ; they also at times take the strangest directions. In certain cases they all turn to the same side and simulate a tuft of moss (Tomes) ; at other times all radiate from the same point of the cavity ; at others they are wholly wanting. In some places the canalicules are seen to point towards the external surface of the cement and the alveolo-dental membrane, from which without doubt they derive their materials of nutrition.

The dimensions of the osteoplasts are quite difficult to determine ; nevertheless, their mean diameter appears to be from .03 mm. to .06 mm. in their longest direction. Kölliker has noticed some so long that they may be compared to the canalicules of ivory, an analogy, says he, which should not be disregarded and which would seem to establish an insensible transition between the cement and the dentine. We have never observed this resemblance, and we find between the two substances a sufficiently well marked boundary never overstepped by the constituent portions of either.

The communication of the osteoplasts and their divisions with the terminal branches of the dental canalicules has been asserted by some anatomists. Kölliker indeed, as we have seen, claims that there exists a system of canals connecting the two, and intended to establish their anastomoses. Hannover denies this, and founds his belief upon the fact that the cement and the ivory are separated by the *stratum intermedium*, a transformation of the *membrana intermedia*, which prevents this intercommunication. Without calling upon this last intervention, which we have always rejected, we cannot admit the possibility of this union between the canals of the ivory and those of the cement. These two substances are very distinct, their structure and their chemical composition are very different, and the modes of nutrition and of development of the two tissues are independent.

### § 2. *Soft Parts of the Teeth.*

Under the name of *soft parts* of the adult teeth we comprehend the pulp or dental germ and the alveolo-dental membrane.

A. Dental Pulp. — The dental *pulp* in the adult is nothing else than the dental papilla of the fœtus, whose volume is enormously reduced by the progress of the tooth-development. It occupies the central cavity in the thickness of the dentine, and is prolonged into the roots through the canals by which these are penetrated. Exactly modeled upon the walls of the cavity that contains it, it represents by its form that of the tooth which covers it: thus, spindle-shaped in the canines, it is beveled to a feather edge in the incisors, and in the molars presents a number of conical projections equal to that of

the tubercles of the crown. Its volume, considerable in the infant, diminishes gradually with age, and in the old person becomes reduced to a thin elongated thread occupying the narrow canal of the root. Finally, towards the term of life it entirely disappears, at which period the incessant production of the elements of the ivory has wholly filled the cavity it occupied.

The dental pulp is, as its name implies, a soft, pulpy organ, of a reddish or roseate color, having at its surface no adherence to the dental wall.

Examined chemically by Professor Wurtz,[1] it was found impregnated with a strongly alkaline liquid, and containing in solution a peculiar albuminoid substance. This substance must be a modification of the albumen which is formed by the action of the alkalies upon it. It is precipitated by acetic acid, and is thus distinguished from normal albumen. The liquid which holds it in solution is incompletely coagulated by heat; it is moreover precipitated by the mineral acids, tannin, and the metallic salts, such as the sub-acetate of lead, sulphate of copper, corrosive sublimate; alcohol coagulates it in thick flocculi. The alkalinity of this liquid excluding the idea of its holding the phosphate of lime in a state of simple solution, it appears more probable that this salt is intimately combined in the albuminoid matter itself.

The dental pulp reduced to ash gave, in the hands of the same chemist, a strongly alkaline residue, in which there was but a trace of phosphate of lime.

From the histologic point of view, the dental germ of the adult differs but slightly from the same organ in the fœtus. It is in fact composed of a fibrous web, quite closely woven, filled with a homogeneous, amorphous

[1] See *L'Union Médicale*, 25th November, 1856.

substance, finely granular and transparent, in the midst of which we find disposed embryo-plastic cells, which may be observed at every period of their evolution. The cells are, however, less voluminous than in the fœtus, but their characteristics are identical. We no longer find in the interior of the organ the calcareous masses and crystals of hæmatoïdin which are noticed in the embryo; but we still perceive, at the surface of the germ, the cellules of the dentine arranged as we have described, and forming a continuous layer.

The vessels of the dental pulp are numerous, whence arises the roseate hue of this part. The pulp receives also as many vascular and nervous branches as the tooth nas roots. These vessels penetrate the organ, ramify there, and terminate in loops at some distance from the surface. The capillaries, according to Kölliker, have a diameter of from .009 to .010 mm.; they belong to the third variety of M. Ch. Robin, and form closely interlocked meshes from which spring the veins. The dental pulp seems destitute of lymphatic vessels, but is extremely rich in nerve ramifications. A nerve filament, having a diameter of from .07 to .09 mm., enters each root, accompanied by several smaller branches, to the number of six or more, of a diameter of from .02 to .05 mm. These branches proceed to the pulp, penetrate it, and there branch again and again, forming a closely woven plexus which terminates in primitive fibres from .002 to .003 mm. in diameter. These fibres in their turn end in loops (Wagner), or by conical or button-shaped terminations.

B. Membrane, or Alveolo-Dental Periosteum. — The dental periosteum is a thin membrane interposed

in the alveolus between the tooth and its socket, and intimately adherent to the cement which it covers throughout its surface. Formed by the thickened external envelope of the follicle, which we have seen fixed to the neck of the tooth, it derives its origin at this latter point, and there takes on a very strong adhesion to the gingival tissue, of which it appears to be merely a continuation; a fact which, in the operation of the extraction of the teeth, sometimes causes laceration of the gum when care has not been taken to isolate the tooth from the soft parts. It proceeds thence towards the tip of the root, sending out here and there loose attachments to the alveolar wall, and, arrived at last at the tip, meets the vessels and nerves of the tooth, upon which it spreads itself in the manner of a sheath, and does not turn back, as has been believed, into the dental canals and cover the surface of the pulp. These vessels, therefore, are not accompanied by the periosteum in their passage to the interior of the tooth, but are in immediate contact with the ivory.

The structure of this membrane partakes at once of the structure of the mucous membrane and of that of the osseous periosteum; thus we may consider it as intermediate between them. It is found to be composed, in fact, of a simple fibrous web, without elastic elements, permeated by a vascular net-work, very rich in vessels, and by numerous nervous ramifications, formed, according to Kölliker, of large tubes. The vascularity of this membrane and its richness in nerves explain the frequent inflammations of which it is the seat, and the acute pains which accompany them.

The alveolo-dental membrane is susceptible of a great many alterations as yet little studied, and in the aged it

seems to undergo a sort of gradual hypertrophy which, concurring with many other causes, finally results in the natural loss of the dental organ.

### (*b.*) ANATOMIC LESIONS OF DENTAL CARIES.

(See the two plates at the end of the volume.)

Having glanced at the normal characteristics of the dental organ, we shall, in the study of the anatomic lesions of caries, and in order to proceed methodically in this investigation, consider this malady by divers stages, equally distinct in their characters, their symptoms, and the method of treatment applicable to them. In this artificial division, which we shall maintain throughout this work, and which seems to us eminently favorable to our description, we admit three successive periods: —

First period. *Superficial caries:* caries of the enamel.

Second period. *Middle caries:* attacking the ivory after having perforated the layer of enamel.

Third period. *Deep or penetrating caries:* that which, having reached the cavity of the pulp, has exposed the organ it incloses.

### § 1. *First Period. Superficial Caries: Caries of the Enamel.*

This caries takes on several forms. When it begins upon a smooth portion of the crown of a tooth, as in very many cases of alteration under the influence of an active and general cause, it appears as a whitish, opaque point, and the enamel has there lost its glassy and transparent look. If at this point an instrument is applied, the tissue of the enamel is found to be friable and chalky, and can be scratched away over a space variable in extent and depth, rapidly finding its way to the surface of the ivory.

If the alteration, in place of originating upon a smooth portion of the exterior surface of the enamel, begins in a break in its continuity, or in a furrow previously existing in the crown, it presents a slightly different character. It must be remarked at the outset that in these furrows, these congenital fissures so frequent in the molars, for example, the enamel may present certain imperfections of structure which will be examined hereafter; it may even be completely wanting. It results from this that the ivory is no longer protected by more than the thinnest layer of enamel, and at the bottom of the furrow is sometimes laid entirely bare. If then there comes about any active agent of alteration, the ivory being directly exposed at the bottom of this primitive furrow, the malady leaps at once to the second period without having passed through the first. This latter form is indeed sufficiently frequent, particularly in accidental caries, that is to say, those which are produced without appreciable direct causes, and which attack only a limited number of teeth.

In all cases, this superficial caries of the enamel once begun presents the following characteristics: The cavity, ordinarily quite minute, is with difficulty penetrated by the point of an instrument; sometimes it affects the form of a very narrow gutter, like the groove itself in which it has originated. The orifice is no larger than the cavity, which sometimes penetrates to the superficial layer of the ivory and has for its depth the thickness of the enamel. Under other circumstances, the malady, spreading over the surface rather than towards the interior, the enamel becomes altered in structure, and broken down through a certain extent; the dissociated and destroyed prisms give to the layer an irregular appearance, covered with

rounded protuberances, or with points sharp and rough to the touch (Plate I., Fig. 1, 2, 3, *d*, *d*, *d*).

Microscopical examination enables us to recognize the following peculiarities. At the border of the exterior orifice of the minute cavity, and around the circumference of the diseased portion, the *cuticle* has disappeared, and if a thin section of a tooth, carious to this degree, is subjected to the action of hydrochloric acid it is seen that this membrane, absent at the surface of the carious portions, is raised at its circumference. Nevertheless, this phenomenon is not constant. It is observed principally in young subjects, in whom this membrane has not yet been worn away by the physical influences to which the teeth have been subjected. Endowed with great power of resistance to chemical action, and capable of offering a serious obstacle to the first attacks of caries, the cuticle, whilst remaining intact, forms an excellent protection to the parts beneath. This explains why the malady most commonly develops itself in these clefts, these natural holes or other faults of conformation, at the surface of which this membrane is wanting by a like congenital solution of continuity. The wear undergone by the teeth during life, and other injuries, may thus destroy it, but the chemical actions properly so called must be endowed with a peculiar energy and prolonged for a length of time in order to soften, remove, and penetrate beyond it.

However this may be, we find no trace of the cuticle on the surface of the carious portion. The orifice of the cavity is ordinarily irregular, slightly bell-shaped, and filled with débris of enamel prisms more or less altered, opaque, brittle, and often reduced to powder. The coloration of the parts is variable. If the caries has progressed rapidly it is white or yellowish; if, on the con-

trary, the progress has been slow or for a time suspended, the coloration is dark, brown, or black. This coloration is due to the deposition of pulverulent matter held in suspension in the saliva or accidentally introduced by the alimentation. These materials are left little by little in the interstices of the dissociated prisms, and fill them, and if by any circumstance, as happens frequently enough, the caries, once set up in the layer of enamel, is arrested either for a time or definitively, it remains permanently tinged with a more or less dark shade. Caries, then, appears in the mouth in the form of spots of various shades of color, indelible, and of a depth often equaling the thickness of the layer of enamel.

We find also in the carious cavity certain alimentary débris and various other substances in minute quantity, which we shall meet again in the more advanced periods of the malady.

Beyond the special alterations in the enamel layer, we find, on examining a thin vertical section of the caries of this period, a phenomenon of great importance, of which the ivory is the seat before it has itself yielded to the invasion of the malady. We refer to a white, transparent zone beneath the altered portion of the enamel layer. This zone has a pretty constant form ; that of a cone with its base turned out to the exterior of the tooth, corresponding to the altered point, and whose truncated summit, turned towards the centre of the tooth, arrives quite rapidly at the wall of the pulp cavity upon the very surface of this organ. This transparent cone, which has already attracted the attention of several observers, Henle, Tomes, etc., should be described in this place, although it belongs, in the different phases of its evolution, to all the degrees of caries. It is the index of

the organic resistance of the dental organ, the proof of the contest which the pulp maintains against the invasion of the disease. Therefore it is not met with, as indeed would be concluded, in the artificially produced caries of which it constitutes very nearly the only difference.

The beginning of this zone, which we shall designate as the *zone* or *cone of resistance*, appears as a minute white speck, situated immediately under the altered enamel, or at a point intermediate between this point and the surface of the pulp, or more rarely in the neighborhood of the latter (Plate I., Figs. 1 and 2, *e*, *e*, *e*). This minute spot enlarges while extending in the direction of the radius of the crown, soon occupying in length the whole extent of this radius (Plate I., Figs. 3 and 4, *d*, *d*). By careful observation under a power of from two hundred to three hundred diameters, we perceive that this zone owes its transparency to an obliteration of a part or the whole of the canalicules comprised within its limits. Its production generally taking place from the circumference to the centre, it results that it follows in its development a progress simultaneous with that of the dental caries and in the same direction, so that the caries, at the moment it penetrates the ivory, meets this homogeneous and resistant layer capable of offering a stay more or less pronounced to its advance. This reaction of the dental organ which has no analogue in the enamel, which passively undergoes the alteration, has its origin in the central pulp excessively stimulated by the external irritation across the thickness of the body of ivory and through the intermediation of the canalicules. This irritation at once gives rise to a functional superactivity of the pulp, and to an excess of production of the mate-

rials which it habitually and permanently elaborates. These new elements, which with Tomes and Owen we will designate by the name of *secondary dentine*, penetrate the canalicules, in them deposit molecule by molecule, fill them, and soon transform the ivory into a compact and uniform mass, a phenomenon which slightly reminds one of the mechanism of condensing osteïtis in certain affections of the bones. (Gerdy.)

This work of superproduction of dentine at the surface of the pulp does not always cease with the obliteration of the canalicules and their anastomoses; for, when this first result is realized, the excitation without doubt persisting in the substance of the pulp, new particles of dentine still go on accumulating, and, as they no longer find at the point of their formation canalicules to fill, they are deposited in concentric layers, and augment the thickness of the region of ivory which corresponds to the external lesion.

This new formation of secondary dentine, to which we will soon recur, necessarily carries with it a proportionate recession of the pulp, which undergoes a progressive atrophy, and the caries, at the moment of its penetration into the tissue of the ivory, thus encounters in a certain number of cases a double resistance from the latter, due in part to its increased density and in part to its increased thickness. It is to the union of these phenomena that caries very often owes its definitive arrest and spontaneous cure by passage to the condition of dry caries, while at the same time this continuous recession of the pulp explains those cases of caries which go on little by little to the total loss of a tooth without occasioning the least pain.

These phenomena of resistance in the substance of the

ivory are not always, we should say, constant, and in the study of the succeeding period we shall see that, in certain cases of caries of a rapid or energetic character, the tooth not prepared for the struggle submits passively to the disease which has attacked it. It then presents no other modification than certain partial obliterations of some canalicules, simple outlines of the cone just mentioned, but without production of secondary dentine in the heart of the central cavity.

### § 2. *Second Period. Middle Caries.*

Middle caries, the second degree of the malady, is characterized by a cavity hollowed in the thickness of the ivory, not reaching the central cavity of the tooth, and communicating with the exterior by an orifice of greater or less extent in the layer of the enamel. The cavity, although irregular, commonly approaches the spheroidal form, the alteration progressing in the substance of the ivory almost equally in every direction, a peculiarity unlike the caries of the enamel, in which the decomposition affects rather the cylindrical form. From the very nature of this second period it results that the enamel which has simply given passage to the disease, and which by its constitution offers to the destructive agents a greater resistance, becomes little by little isolated from the softened and destroyed ivory lying beneath. It thus forms the external wall of the cavity, a wall friable, thin, and which may give way unexpectedly, either spontaneously or in consequence of a shock or a pressure, discovering thus a cavity which might otherwise have remained a long time unperceived. It is this circumstance of a caries of the ivory with a minute orifice in the enamel, an orifice oftentimes concealed in a dental fis-

sure, that has caused the belief in the existence of internal caries, which rigorous observation has never demonstrated.

The nearly spherical form of the cavity of the caries, although the most frequent and representing perhaps the typical form, is nevertheless not always found; it is common when the caries has its rise in a preëxisting furrow or fissure with congenital absence of the enamel layer; the alteration then really beginning in the ivory causes this to undergo a progressive and regular destruction (Plate II., Fig. 3, *c*). If the caries arises, for example, upon a smooth portion of the crown under the influence of an active and general cause, the form will be different. It is in this case spread over the surface, and the orifice of the enamel is often of the same size as the cavity of the ivory, or larger (Plate II., Figs. 4, 6, 7, *d*). It is also thus when the caries is produced under the influence of the presence or of the pressure of a foreign body, such as the clasp of a plate of artificial teeth, etc., circumstances in which the cavity takes the form and the direction of the object which has favored its production.

This form may also vary singularly, according to the nature of the tissue of the ivory, more or less resistant or friable in different subjects, and also according to the degree of development of the cone of resistance, whose mode of formation we have already described. If this homogeneous zone has not had time to form, as happens in the case of rapid caries invading the ivory and taking it by surprise, so to speak, the caries proceeding regularly will take the spherical form; if the zone is strong, compact, and dense, as in the case of slowly progressing caries, which has produced in the pulp a continuous and prolonged excitation, the disease then finds itself in the

ivory in presence of a material and often considerable obstacle, which may either force it to change its direction, causing it to spread itself more or less extensively over the surface of the tooth, or check its progress completely and bring on the formation of dry caries (Plate II., Fig. 1, *d*, *d*).

There is a species of caries to which we desire to direct attention on account of its special characteristics in form and appearance, namely, the caries of the necks of the teeth. Situated at the very base of the crown and at the border of the gum, it takes almost constantly the form of a narrow gutter following the line of the gingival curve. From its peculiar situation at a point of the tooth covered by only a thin layer of enamel, it results from the start that this caries is very sensitive, through the rapid exposure of the ivory.

The circumstances which bring on this special form are inflammatory conditions of the free borders of the gum, or the masses of concreted mucus which remain at this point in contact with the teeth during the course of certain diseases. A fissure thus formed has its length in a direction at right angles to that of the tooth and ordinarily remains quite narrow; characteristics which have given it the name of serpiginous caries, a term used by Delestre to designate it.[1] This alteration, from its beginning thus disposed in linear form, may pursue consecutively the progress of ordinary caries, and, following in its development one horizontal course, finally cause complete section of the crown. It may also, after a certain time, pass to the condition of dry caries. The cavity then presents a singular appearance, not unlike that of a saw-cut, with smooth, polished, hard, and resistant

[1] *Du Ramollissement des Gencives.* Thèse inaugural, 1861, p. 14.

walls (Fig. 1, *a a*). These are the cavities which Duval and several other authors designate as *caries taking on the look of wear*, and whose mode of production has not been explained. They do, in fact, have every appearance of veritable wear by friction, but our observations upon the succession of the different periods of the malady have proved to us that these fissures so nicely polished are nothing else than caries of the tooth-neck passed to the condition of spontaneous cure, or dry caries.

FIG. 1.

The wall of a cavity of caries of the second period examined with an excavator or a file is found to be softened in proportion to the rapidity of progress of the disease, and to the energy of its active cause; the instrument penetrating easily through the mass and thus showing the thickness of the softened layer. This may be removed piecemeal in layers which present every appearance of ivory artificially softened by acids. It is whitish or of a slightly yellowish tint, at times brown or black, but these differences of color, like those of the enamel in the first period, have no importance and no signification.

We should distinguish, in the examination and appreciation of the extent of a case of caries, the apparent dimensions with the softened layer of ivory covering its bottom, and its real extent after this layer has been removed. The difference is at times considerable, so that a very minute cavity, its softened portions being removed, may increase to double or triple its apparent extent. It may also result from this that the caries, having once

reached its resisting and normal wall, may approach so near the cavity of the pulp that this organ, without exactly being exposed, is protected only by a layer of more or less altered ivory, although capable of again returning, by means of appropriate treatment, if not to its original organization, at least to a certain degree of resistance and density.

Examining with the microscope a thin section through the middle of the exterior orifice of the caries and the centre of the cavity of the pulp, we observe the following peculiarities : —

The borders of the enamel at the edge of the external orifice are friable, chalky, and show traces of profound disorganization, which is prolonged to a certain extent at the sides (Plate I., Fig. 4, *d*). These enamel borders may still retain a certain power of resistance, so as to cover the subjacent cavity, which, by its increase, isolates and detaches them more and more. Beneath these borders are found the softest portions of the wall, yellowish, transparent, and amber-like ; here, also, we distinguish in some fragments traces of the original organization and some fascicles still visible of canalicules (Plate II., Fig. 2, *d*). Below these layers, whose softness decreases as we approach the centre of the tooth, we meet with transparent, homogeneous laminæ of ivory, deprived of their canalicules which are obliterated, and in some sort surrounding the parts before mentioned ; deeper still the substance of the ivory remains normal, or presents traces of a certain degree of organic resistance by its passage to the compact state.

Arrived at this point of the preparation, the observer finds, at the deepest limit of this layer, the central cavity, whose contour and contents may continue regular and

normal, but often present more or less considerable evidence of disturbance. When the caries by its progress has produced on the part of the tooth the various phenomena of resistance which we have already described, the pulp cavity may have lost its original form by the production of a layer of secondary dentine more or less developed at the point which corresponds to the caries. This product may take the most varied forms. At first it is a slight enlargement projecting into the cavity (Plate I., Fig. 6, *e*). At other times we find a protuberance of greater volume, like a minute bony tumor, adhering by a sort of pedicle to the point of the cavity corresponding to the alteration in the ivory (Plate I., Fig. 7, *e*). Under other conditions where the functions of the pulp have been more brusquely assailed, we notice a kind of partitioning irregularly subdividing the organ into several portions (Plate II., Figs. 1 and 2, *e*). Finally, the pulp has sometimes disappeared entirely under progressive invasion of the secondary dentine, which has completely obliterated the central cavity as well as its prolongations into the roots, and thus represents a mass of dentine regularly occupying the cavity of the tooth, whose exact form it takes and preserves (Plate II., Fig. 3, *d*, and Fig. 4, *a* and *b*).[1]

[1] This production of secondary dentine invading the pulp had already attracted the attention of several observers. In 1820, M. Emmanuel Rousseau, in an inaugural thesis on *The Two Dentitions*, had remarked, in the central cavities of some teeth, hard concretions like calculi. Antoine Desmoulin had also remarked some analogous productions normal in the pulp of the teeth of the Moose (*Dictionnaire d'Histoire Naturelle*, de Bory de Saint-Vincent, art. Dent). Finally, the Elder Tomes, and after him Salter and Albrecht, perceived the relation which exists between these dentinal products and the progress of the caries (see Tomes, *Lectures on Dental Physiology and Surgery*, 1848, p. 207; Salter, *Transactions of the Pathological Society of London*, vol. iii., p. 164; Albrecht, *Die Krankheiten der Zahn-pulpa*, Berlin, 1858).

This phenomenon of the complete *dentification* of the cavity of the pulp which takes place normally in the aged with the spontaneous loss of the teeth, and which is, in such case, a curious phenomenon of the pathology of caries, does not always follow this progressive and regular advance resulting in the complete disappearance of the pulp and substituting therefor a mass of ivory of like form and volume. In a certain number of cases the phenomenon proceeds irregularly, so that in place of a regular block, there are found in the middle of the cavity and among the débris of the more or less modified pulp, hard fragments adhering sometimes to a point of the wall and forming incomplete partitions in the cavity, and sometimes free and isolated, having the appearance of minute calculi. The latter is especially the case when by its rapid advance the caries has excited in the substance of the pulp multiple points of irritation which have caused the local production of irregular masses of ivory.

Placed under the microscope and examined with a power of about three hundred diameters, these minute objects, or fragments of them, as well as the laminæ taken from the dentification of a central cavity, present the same character as is recognized in the secondary dentine of the aged, that is to say, a nearly homogeneous and translucent mass, in the interior of which are remarked here and there a few irregular groups of parallel canalicules, rarely anastomosing and without issue. The fundamental substance of the ivory presents at all points the aspect and texture which it has in the normal tissue. The canalicules seem to be more sinuous and of a larger than the normal diameter. Our measurements have in fact shown that their diameter was from

.003 to .005 mm., while the normal dimensions average from .0015 to .002 mm.

If, after this examination of the anatomic constitution of the wall of a caries of this second period, we proceed to the study of its contents, we find it represented by a soft pulpy mass whose reaction, observed directly upon litmus paper wet with distilled water, is distinctly *acid*. This fact, already remarked by Tomes, has been found constant by us whenever we have experimented upon the contents of caries in a state of progress, whilst those in a state of suspension or arrest, as dry caries, do not present the same reaction, and may appear either alkaline or neutral, conditions corollary to their state of suspension.

This pulpy mass, considered as to its composition, incloses a crowd of diverse elements, originating either in the tooth itself or from alimentary débris or other foreign substances.

The débris of dental origin are primarily enamel prisms, more or less altered, sometimes still united in bundles, or isolated and broken. The alteration of which they are the object is recognized by their greater clearness of definition, and the irregularity of their greatly darkened contours, as well as by the finely granular and opaque condition of their mass. The darkened contour, especially of the prisms still grouped together, indicates that the disease has penetrated them and has begun their isolation, one from another. At other times we perceive these same prisms so reduced and bruised, that only by their minute fragments do we recognize their previous constitution (Plate II., Fig. 8, *b*, *b*, *b*).

Side by side with these débris of enamel, there are found others more numerous and of a larger size which

come from the ivory. These are minute, softened laminæ, of a gelatinous consistency, whitish, or of a yellow or brown shade of color, in which we still recognize by some fascicles of broken canalicules, the original conformation. Sometimes these fragments, under the microscope, present their length, at others their transverse or oblique section, showing the orifices of their canals or even a small extent of their interior. These fragments, also, sometimes permit us to see on the broken margins of the preparation one or more detached filaments, which are no other than the very walls of the canalicules isolated by the disease (Plate II., Fig. 8, *a*, *a*, *a*).

Upon examining with a sufficient power certain of these imperfectly obliterated canalicules, we find, upon careful observation, that the interiors of these tubes are often filled with granulations of great minuteness. Those whose examination can be carried no farther, are either of a calcareous or phosphatic nature, due to the constant excitation of which the pulp is the seat, or else of external origin, coloring granulations of the nature of those which penetrate the tissue of carious teeth, and give them their darkened tints. Some very thin laminæ, whose surface is perpendicular to the direction of the canalicules, present to the eye the form of a sieve filled with minute orifices, which, having no great length, appear as white points bounded by well-defined dark-colored contours. The observation of these laminæ thus shown enables us also to see, under a very high power, in the open passages of these canalicules and adhering to their walls, some masses of granulations which are without doubt of the nature of those of which we have just spoken.

The other substances found in the contents of a carious tooth are : —

Pavement epithelial cells detached from the buccal membrane (Plate II., Fig. 8, *e*) ;

Globules of grease from the food ;

Mucous globules or leucocytes (*d d*) detached from the parts near the gum ; and finally, vegetable parasites and infusorial animalcules to which in certain theories of dental caries (Ficinus), has been attributed an important rôle.

The vegetable parasites are of two species : first, a filiform alga, *Leptothrix buccalis* (Robin), represented by filaments, sometimes innumerable, in a tangled mass, and presenting in some places short subdivisions (*e*) ; second, a species allied to the Oïdium of thrush (*f*), but in smaller quantity than the former.

The animal parasites are vibrios, the *Vibrio lineola* (Ehrenberg) (*g*), very abundant in some caries, rarer in others, and whose presence appears to play no very evident part, as do the vegetable parasites, in the production or in the progress of the malady.

The dental caries, or rather its contents, have a certain odor, which varies sensibly according to the cases. The cavity itself, that is to say, the softened ivory, presents but a faint, slightly nauseous odor, which is also to be noticed in the breath of many patients who from some general cause, have at one time a great number of carious cavities ; but this odor is rarely alone ; to it are added most generally the putrid gases resulting from the decay of alimentary or other substances, in the centre of the cavity.

The distinction between the various odors of the mouth, of the pharynx, or of the respiratory passages, and that of caries, is not always easy. Caries may present in this regard three characteristics : first, the faint

odor; second, the putrid odor; third, the gangrenous odor. This last is perceived only when the malady has reached its third period, and the tissue of the pulp has undergone either a partial or total destruction by gangrene, following upon inflammatory symptoms. Thus caries which, under certain simple circumstances, can present but a feeble odor, merely a little faint, may in other cases, and at an advanced period, bring together these diverse exhalations, and become for the mouth a veritable centre of infection.

To this anatomo-pathologic study of the second period of the malady, we should add the examination of the characteristics of caries spontaneously arrested, or *dry caries.*

If we make a section of a tooth affected with caries of this nature (Plate II., Fig. 1, *d d*), we observe the following characteristics: The external surface of the ivory, irregular, polished, and of great hardness, is colored yellow or brown, more or less dark, bounded at its edges by débris of enamel whose alteration is likewise suspended. The compact and homogeneous tissue seems at first sight to present no trace of organization, yet we always find here and there some short bundles of sinuous canalicules buried in the midst of the uniform and transparent mass. The thickness of the ivory thus transformed is considerable, for it always extends beyond the wall of the pulp, and even, as we have seen, at times invades the whole of this cavity, which a product of the same nature completely fills. All this mass upon which rests the surface of a dry caries is nearly twice as hard as ordinary sound ivory, and very well explains the completeness of its resistance to the progress of the disease.

§ 3. *Third Period. Deep or Penetrating Caries.*

In this third degree of the malady the change has invaded the whole depth of the tooth, uncovered the central cavity, and for its extreme limit looks to the total disappearance of the crown and the complete softening of the roots.

At the moment when the caries, passing the wall of the pulp cavity, brings this organ in contact with the external air, it puts on, by reason of these circumstances, a peculiar appearance. Examination enables us to perceive that at the beginning of this period the communication is effected by means of an opening or canal situated in the deepest part of the cavity. This canal is at times very short when the caries is of wide extent, or when it meets an elevated point of the central cavity; sometimes quite long, oblique or sinuous, when phenomena of active resistance have modified the parts.

The consistence of the inner wall of penetrating caries is also very variable. In certain cases, the tissue of the ivory is so spongy that an instrument, as an excavator, may, without the least effort, lift off or penetrate the partition, and open a wide communication between the two cavities. Under other circumstances the bottom of the caries is of considerable density; the opening is difficult to find; its walls are very hard; all the neighboring portions of the ivory are resistant, brown or black. Cases of this kind are remarkable, in that we often find no trace of the pulp which has disappeared by gangrene or by suppuration, and that they are complicated with chronic periostitis, with or without purulent drainage, by way of the root canals.

In all the cases the lesion presents the form of two

superposed cavities, that of the caries and that of the pulp, united by an intermediary canal. The characteristics of the former cavity, that is to say, of the caries, having been already described in the preceding paragraph, we need not recur to them again, but will proceed to consider the state of the pulp cavity and of the canal uniting the two.

This inner cavity, filled normally by the central organ of the tooth, whose exact form it represents, undergoes various changes in this period of invasion. The orifice of communication of the carious cavity with the pulp takes different forms; at times it is of considerable extent and irregular, resulting from spontaneous or artificial breaking down of the inner wall of ivory; at times it is so narrow that it hardly permits the passage of the finest probe, and must be enlarged and shaped to properly disclose the condition of the deeper parts. In such circumstances, in place of one orifice of communication, we sometimes find two, and even three, as may be produced, for instance, at the bottom of wide-extending and long-standing caries. Beyond these parts the pulp is found with the lesions proper to it.

This organ, suddenly exposed to external agents, immediately shows inflammatory symptoms of varying intensity which, by certain alterations, are betrayed to direct observation. If the exposure is recent and of small superficial extent, there will be perceived a slight injection of little depth and localized upon the very point of the denudation, the rest of the organ retaining its normal character. If the penetration of the pulp is of long standing, the inflammation will have attacked a larger proportion of the mass which is then tumefied and of a darker or lighter shade of brick-red, presenting at some

points hemorrhagic centres, recognizable by the naked eye by minute black specks inclosed within the injected tissue. In circumstances still farther advanced the pulp is notably reduced in its volume, and the portions remaining have entered upon a state of permanent suppuration, or have undergone a partial wasting subsequent upon gangrene. The organ is then found in a state of fetid and formless putridity, in which the most minute examination scarcely finds a trace of the primitive organization.

Other peculiarities are also found in the pulp so modified; if, even after its denudation, the irritation has been slight, as is the case in slowly advancing caries, there is produced a hyper-production of dentine upon the point exposed, and it then follows that the canal leading to it, after having remained open a certain time, becomes so obliterated by this secondary production of ivory, as to carry back the caries to the second period. This spontaneous phenomenon, whose mechanism may be utilized in the therapeutics of the malady, opposes some resistance to its progress. If, on the other hand, the caries has advanced with rapidity, and the perforation is large, the pulp is inflamed sometimes in a part of its substance, sometimes throughout, and presents to our observation the characteristics and the ordinary products of the inflammation of soft and vascular tissues; this inflammation offers in its progress alternations of recrudescence and of calm, such that the organ whose functions are temporarily suspended, may resume them, but ordinarily in an irregular and abrupt manner. It is these alternations which give rise to the production of laminæ or fragments of secondary dentine, which we have remarked, at times under the form of incomplete partitions, at

others as minute spicules of bone or calculi included in the substance of the more or less modified tissue.

Other accessory changes are also remarked in certain cases of caries; the cavity, for instance, is observed to be occupied or entirely filled with soft masses engorged with blood. These products originate in several ways: sometimes they come from the gum irritated by the neighborhood of the disease and become the seat of fungous growths; they are then absolutely distinct from the dental organ itself, and present the ordinary composition of this kind of alterations; sometimes we observe products developed from the periosteum in cases of caries invading the neck of the tooth, or having its origin at this spot. They are then veritable polypi whose mass occupies the carious cavity, and whose pedicle is attached to the terminal border of the periosteum; sometimes there are real tumors of the pulp, formed by direct hypertrophy of that organ, which is thus projected from its natural cavity, in form of a soft, rounded, congested mass, in which examination under the microscope recognizes the constitution of the normal pulp. In another work we have remarked and described these alterations, and have but to reaffirm our assertions here.[1]

This condition of the disease with various complications on the part of the pulp is not of constant occurrence; and in certain cases of caries, which penetrate abruptly the central cavity, this organ may be attacked by an inflammation so general and violent as at once to bring on gangrene and its entire disappearance. The cavity remains, thereafter, entirely free and permits the entrance of the exploring instrument into every part;

[1] See *Mémoire sur les Tumeurs du Périoste Dentaire*, 1860, pp. 56 and 58, and Plate, Figs. 6 and 7.

the opening, enlarged little by little by the progress of the malady, allows the two superposed cavities of the pulp and the cavity of decay to become united, and the destruction, continuing its course, causes the walls of the carious cavity proper to disappear. Then the pulp cavity in its turn becomes that of the caries itself, and finally, this giving way entirely, the dental organ is reduced to the roots which still keep their place in their alveoli. These roots when examined are found to be but small softened and spongy masses, which an instrument penetrates with the greatest ease, and a more minute examination of a section shows them to be but softened and passively disorganized ivory.

## CHAPTER II.

### ETIOLOGY AND EXPERIMENTS.

The examination of the causes and general conditions under whose influence dental caries is produced is divided into several branches.

1. The predisposing anatomical conditions and the constitutional causes.

2. The rôle of the saliva considered as the agent of the production of caries.

3. The production of artificial caries by direct experiment.

4. The mechanism of the production of dental caries.

### § 1. *Anatomical Predisposing Conditions, Various Constitutional Causes.*

The anatomical conditions of the exterior conformation and of the internal structure of the teeth, playing in the production and progress of the caries a most important part, we should study them not only in the characteristics they present, but also in the diverse influences, hereditary or acquired, which cause them.

A. Anatomic Congenital Conditions: Vices of Conformation. — The dental organ at the moment of its eruption, presents, as is well known, the form and the volume which it preserves during the whole duration of its presence in the organism; its interior constitution

alone is incessantly modified by a series of molecular phenomena of nutrition which we have not to study here. Now, the external form of the tooth may approach with greater or less exactness absolute perfection, and at times even attain to it, as is observed in certain families and races, in which the beauty of the teeth is hereditary and constant.

This regularity of external form evidences quite frequently the perfection of the internal constitution, and the union of these two circumstances gives to the tooth such power of resistance that, in the absence of a constant or energetic altering cause, caries is never developed therein. On the other hand every defect of the surface, or of the interior composition produced, whether by hereditary predisposition, or by accidental troubles during the intra-follicular period of the tooth, remains after its eruption forever irreparable and indelible. Examples of anatomically irreproachable dentition are rare, especially under the conditions of our ordinary social life, so frequently disturbed by morbid accidents; now, there is perhaps no organ which yields to the influence of the general conditions of the constitution and the changes of the health more easily than the tooth.

The congenital imperfections of structure we are about to study are of two kinds: superficial and directly visible; internal and inappreciable by the naked eye.

The external imperfections, whose form and physiognomy vary infinitely, consist most commonly of vices of conformation of the enamel layer; these are dark colored, tortuous, irregular grooves in the masticating face of the molars, in the interstices between the tubercles, — grooves which the finest probe penetrates with difficulty, and which are filled with alimentary detritus and the

fluids of the mouth. Examined in a vertical section under the microscope (see Pl. I., Figs. 1 and 2, *d*), these grooves appear as narrow *culs-de-sac* whose bottom corresponds to a point approaching more or less near the layer of ivory, and sometimes actually reaching it so as completely to expose it. The wall of this gutter is rough, uneven, and studded with débris of enamel prisms, either incompletely calcified and friable, or running in a tangle in various directions, in such a way as to inclose open spaces, thus rendering the teeth very fragile. These grooves, though sometimes long and sinuous, are often found as simple circular perforations. All their characteristics resemble closely those of caries of the first degree, and were it not for the special intra-follicular causes which have given them their origin and their stationary condition, they might be taken for veritable caries.

All these imperfections of the enamel layer have not the same appearance of elongated grooves or furrows, or of circular holes, and sometimes there is found an entire congenital absence of this tissue over a considerable space. We see at such times upon a tooth a sunken, irregular hollow, colored at the bottom yellow or brown, at whose surface the instrument encounters no enamel. In simple cases, the enamel is not pierced but simply sunken, presenting only a simple depression without alteration of tissue.

This disposition is often seen on the external face of the first lower molar, on the posterior surface of the upper incisors, in the interstice of the two cusps of the bicuspids, etc. A certain relation always exists between the simple depressions and the perforations or furrows, these two states representing two different degrees of the same disposition.

To the faults of conformation just described there must be added another which, by its more extended and more general character, constitutes a grave predisposition to caries; we refer to *erosion.*

Erosion is characterized by an alteration of the crowns of the teeth, which, at the moment of eruption, appear as if worn or corroded for a certain extent of their length. This injury takes so specific a form that it is not possible to confound it with other lesions; it is always in horizontal furrows, sometimes simple, at other times double or triple for each tooth, but always superposed and parallel, and placed at exactly the same level upon homologous teeth; for this lesion is never found exclusively upon a single tooth, but is common to the similar teeth of the same jaw, or simultaneously of the two jaws. The inferior and superior incisors, and the four first molars are the most commonly affected, and when a considerable number of the teeth present this lesion in a marked degree at the same time, the mouth has a most unsightly appearance: the teeth are furrowed in transverse ridges of greater or less size, but always of a yellowish or brownish color, and on the crown rough, irregular, and deformed. In some cases there exists but a single, very large furrow, occupying, it may be, even a third or a half of the length of the crown, and appearing like a wide gutter bounded by two ridges of enamel. In the molars these furrows are often less clearly defined, and the crown presents a mass of irregularities, points, and cavities, always occupying the same region bounded by horizontal limits. Observed with the naked eye, these imperfections are evidently caused by a loss of substance, or by a congenital absence of the enamel tissue, in such sort that the ivory in its most superficial layer is exposed. But

under the microscope an examination of a complete section of an eroded tooth shows very interesting peculiarities in the depth of the ivory in intimate correlation with the external lesion. If, in fact, we examine a section of this kind at first under a low power (five diameters), we remark (Plate II., Fig. 5) that the enamel is all irregular, jagged, fractured, presenting hollows and perforations; then, below it, and in the thickness of the ivory, we find a series of dark, stippled layers, disposed in concentric and parallel lines, following the curves and sinuosities of the crown. These layers, whose number varies according to the degree of the erosion, rarely exceeding three or four, are nothing else than continuous rows of globules of dentine with their interglobular spaces.

Then if we place this same section under a power of two hundred diameters (Plate II., Fig. 6), we perceive that the prisms of the enamel are dissociated, broken, running in various directions without order, and that the superposed layers of globular dentine have all the appearances and characteristics which we have assigned to this order of lesion.[1] The intensity of the alteration always decreases from the circumference towards the centre, in such a manner that it becomes very slight or nearly lost at the third or fourth layer, which seems to indicate that the first arrest of development, which has produced the external layer, has been considerable, but followed by others less prolonged or less abrupt, or else that some phenomena of molecular reparation have been able during the period of evolution to fill up the interglobular spaces in the layers nearest the centre. Thus we see that erosion, besides giving a tooth these external, irregular, and deformed appearances, brings to the

[1] Vid. *Développement et Structure des Dents Humaines*, 1858, p. 34.

interior of the organ imperfections of nutrition, which give to the tissue a friability and a permeability that prepare it in the most serious manner to undergo ulterior alterations, and more particularly caries. This is not precisely the case with congenital lesions of the enamel, the grooves and crevices, which we have previously studied, for these may be exclusively confined to this tissue without entering into the mass of the ivory, and consequently do not constitute so serious a predisposition, if not for the original production of caries, at least for its progress throughout the dental organ.

The explanation of the congenital alterations of the teeth belong, we repeat, to the history of the follicular evolution. They are due, in fact, exclusively to arrests or perturbations of the very formation of the dental tissues. Thus, when, during the protracted period of dentification, there arises no disturbance, either local or general, in the health, the phenomena taking place in a regular and continuous manner, the tooth at its eruption presents an exterior configuration and an interior composition alike normal and homogeneous. But, if, on the contrary, there happens during infancy a local lesion in the neighborhood of the follicle in the way of development, or a more or less grave affection of the general economy, eclampsia, eruptive fevers, intestinal disturbances, etc., there results, according to the character, the gravity, and the duration of the disease, either a simple disturbance, and later there is observed some one of these slight imperfections of the crown, or a complete suspension of the formation of the enamel and of the ivory, shown by the characteristic furrows of erosion. Now, as the two tissues, ivory and enamel, are formed simultaneously or nearly so, at least as concerns the crown, the

alteration effected in the enamel, and which remains external, is found reproduced in the layer of ivory formed at the same moment, and if the enamel shows superposed furrows, indices of as many troubles interrupting the work of dentification, we find in the ivory a like number of layers of globules and of interglobular spaces.

The explanation we here give of the formation of the superficial and internal lesions that constitute erosion, is not admitted by all authors. Some attribute them to a change of a chemical nature, taking place at the very surface of the tooth during one of the phases of eruption, at the moment when the crown, incompletely erupted, at the surface of the pierced gingival border, becomes covered with abundant mucus, the result of hypersecretion under the influence of an intercurrent affection. Further on we shall again meet this phenomenon in the mode of production of caries in the adult. That this is not the correct explanation is shown by this, that, if the alteration were chemical in its nature we should find no corresponding change in the centre of the organ, and, moreover, careful observation affords it no shadow of probability.[1]

[1] *Observation.* A girl of nine years was offered for our examination, with a most marked erosion, occupying the incisors of both jaws, and the four first permanent molars. Moreover, these were the only teeth of the second dentition which had erupted. The remaining temporary teeth were normal. The erosion occupied on the incisors of both jaws two thirds of the height of the crown. The whole of the diseased portion, from the free edge, was considerably shrunken, absolutely destitute of enamel, soft and sensitive to the touch of an instrument. The lateral incisors showed the alteration to a less degree, confined solely to the free edge which presented some indentations and knobs of enamel. The four permanent molars were absolutely deformed by the same alteration, which rendered them almost unrecognizable, and there were found only prominences indicating the tubercles in the midst of the softened masses of a general caries of the whole crown.

Inquiring of the antecedents we learned that this child, from the age of

The congenital lesions of the teeth, fissures, erosion, etc., are then exclusively due to intra-follicular disturbances of the dentification. Now, these disturbances when they occur, ought necessarily, owing to the law which governs them, to be produced simultaneously and in the same degree in all the teeth which are at the same moment in the process of dentification. This is, in fact, what happens, and here is found the explanation of identical congenital lesions upon homologous teeth, and consequently of caries which has the same relative position. It is not then surprising to see two molars, for example, or two incisors on opposite sides of the same jaw, presenting the same fissure, the same crevice, the same congenital cavity, and in consequence one position, one progress, and one identical form of their two parallel cases of caries.[1]

These considerations bring us to the study of the place commonly chosen by caries, the teeth most frequently attacked by it, and the points of these teeth where it more generally begins.

two years, had never been affected by any disease, nor had ever been confined by any indisposition; but at the age of one year she had had a severe attack of eclampsia, which for a fortnight had endangered her life. Now this epoch corresponds precisely to the period of dentification of the eroded teeth, this having been completed at that time for the temporary teeth, and not yet begun for the rest of the permanent dentition.

We could multiply these observations, but they would teach nothing more than does this example, than which nothing can better show the relation between cause and effect.

[1] We may compare the erosion of the teeth with the transverse grooves observed upon the nails or upon the hoofs of the solipeds consequent upon diseases, and remarked especially by Beau and Reynal. These grooves are likewise due to disturbances in nutrition; but, whilst these are transitory, in consequence of the incessant renewal of the nail, those of dental erosion are indelible.

We may at the outset assert that the teeth most predisposed to caries are those which accomplish their evolution and their eruption at the period of infancy most disturbed by diseases, so that, in a general way, the conditions of the health always govern, in a certain degree, the constitution of the teeth. This is evident not only for the temporary but also for the permanent teeth. Thus, when, during the evolution of the first teeth, that is to say, during pregnancy, the health of the mother or that of the fœtus itself is disturbed, the structure and interior formation of the deciduous teeth are proportionally affected; hence arise those cases of caries which, without appreciable cause, so often attack the teeth of infants, sometimes bringing in their train serious local and general disorders.

The same phenomena are observed when, in extreme infancy, the epoch to which the formation of the permanent teeth corresponds, analogous disturbances take place, bringing with them the same consequences.

It is thus that the marked predisposition to caries shown by the first molars is explained, their period of intra-maxillary evolution is so long and so exposed to these perturbations.[1]

[1] We know indeed that these teeth, whose bulb appears at the fourth month of intra-uterine life, effect their eruption only at the sixth year, thus remaining shut up in the jaw during a period of nearly six years. Nevertheless, this is not the only tooth whose evolution is so protracted; the follicle of the second molar appears, according to our own observations, towards the end of the second year, while its eruption does not take place till the twelfth year. It remains, therefore, enclosed during ten years in the interior of the jaw. The same is the case with the wisdom-tooth, the first trace of which is observed at twelve years, and its eruption at the eighteenth at the earliest. These facts may reasonably be cited in explanation of the comparatively high figures representing the molars in the accompanying *résumé*.

The teeth which have undergone these various kinds of deviations, or those which by compression or other cause have become notably atrophied, as the wisdom-tooth, are equally subject to it.

We give herewith a series of figures indicating the proportion of affected teeth of the permanent set in a total of ten thousand cases of caries.

*Table of the Distribution of Dental Caries occurring upon the Different Classes of Permanent Teeth up to the number of* 10,000.

| | | | | | |
|---|---|---|---|---|---|
| Central incisor | 642 | upper, | 612 | right, | 304 |
| | | | | left, | 308 |
| | | lower, | 30 | right, | 20 |
| | | | | left, | 10 |
| Lateral incisor | 777 | upper, | 747 | right, | 369 |
| | | | | left, | 378 |
| | | lower, | 30 | right, | 20 |
| | | | | left, | 10 |
| Canine | 515 | upper, | 445 | right, | 198 |
| | | | | left, | 247 |
| | | lower, | 70 | right, | 20 |
| | | | | left, | 50 |
| 1st Bicuspid | 1,310 | upper, | 940 | right, | 345 |
| | | | | left, | 595 |
| | | lower, | 370 | right, | 170 |
| | | | | left, | 200 |
| 2d Bicuspid | 1,310 | upper, | 810 | right, | 400 |
| | | | | left, | 410 |
| | | lower, | 500 | right, | 270 |
| | | | | left, | 230 |
| 1st Molar | 3,350 | upper, | 1,540 | right, | 728 |
| | | | | left, | 812 |
| | | lower, | 1,810 | right, | 910 |
| | | | | left, | 900 |
| 2d Molar | 1,736 | upper, | 690 | right, | 380 |
| | | | | left, | 310 |
| | | lower, | 1,046 | right, | 497 |
| | | | | left, | 549 |
| 3d Molar | 360 | upper, | 220 | right, | 100 |
| | | | | left, | 120 |
| | | lower, | 140 | right, | 60 |
| | | | | left, | 80 |
| Total | 10,000 | | 10,000 | | 10,000 |

From the examination of this table we notice that generally speaking caries affects the upper more frequently than the lower teeth; the figures giving 6,004 upper against 3,996 lower, or about 3 to 2. Yet we find that this proportion, true for the teeth as a class, is not so for the first and second molars, in which caries is more frequent in the lower jaw. Comparing the opposite sides of the same jaw, we do not find a difference sufficiently marked to be taken into consideration, and may assert that caries is equally frequent on the two opposite sides of the same jaw. The two sexes present a difference in the predisposition to caries which, although slight, is worth noting; thus, in a total of 1,000 cases in adults we have found 583 in the woman and 417 in the man, placing the sexes from this point of view in an approximate ratio of 3 to 2.

The age of the patients and the period of its greatest frequency ought likewise to be determined. We have for this purpose prepared charts showing lines extending from the moment of the eruption of each tooth up to the age of seventy, that extreme time of life when the loss of the organ is a physiological act, and when, moreover, caries is extremely rare; the highest point of the line representing the age at which caries is most frequent for each particular tooth. These tracings, already used by Tomes[1] in the determination of the loss of teeth from various causes, are here limited to the study of dental caries. They are the result of our own personal observations, and comprehend, as will be seen, in the same chart, the two curves comparing the homologous teeth of the two jaws.

The tracings, which may be considered as representing

[1] *Lectures on Dental Physiology and Surgery*, 1848, p. 144.

the course run by caries in all classes of teeth, show a certain number of pauses or breaks corresponding to the different ages adopted as starting points. These interruptions, applied in a uniform manner throughout the series, are necessarily common to the two lines contained on the same chart.

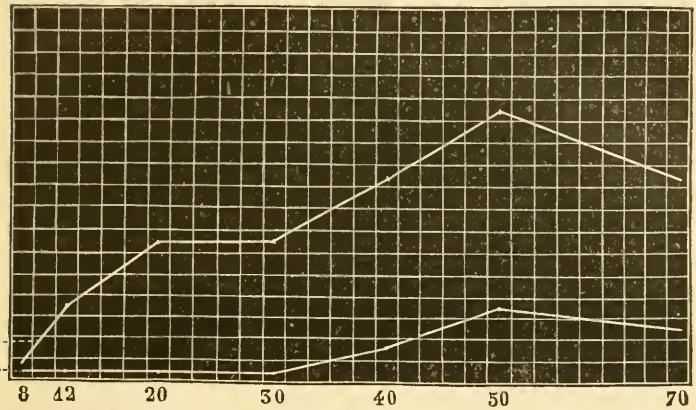



FIG. 2. Tracings representing the Relative Frequency of Dental Caries for each year in the Central Incisors. A. Line for the upper incisor. B. Line for the lower incisor.

These two curves show that caries is greatly more frequent in the upper central incisor than in the lower; that for the former it increases from the age of eight years up to twenty, remains stationary from twenty to thirty, then begins again, to attain its maximum at fifty years; whilst that of the lower incisor, almost *nil* up to thirty, from that time slowly increases up to fifty years; that, finally, the ratio of the lower is to that of the upper as four to thirteen.

The examination of the two following lines indicates at first a relation between them analogous to that of the preceding chart. The caries of the upper incisor, already frequent at twelve, increases from that age to reach its maximum at thirty years; that of the lower, *nil* up to

the age of twenty, increases up to forty, and the maxima are in the ratio of three to eleven.

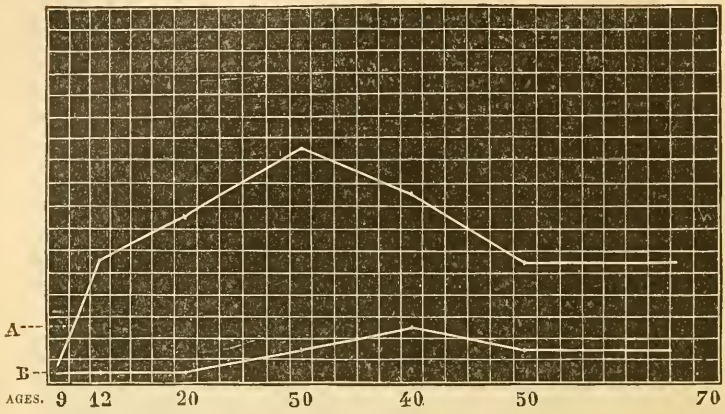



FIG. 3. Tracings representing the Relative Frequency of Dental Caries for each year in the Lateral Incisors. A. Line for the upper lateral. B. Line for the lower lateral.

The results furnished by the curves relative to the incisors are generally correspondent to the observations of ordinary practice. It is in fact constant that caries specially affects the upper incisors, while it spares, sometimes through life, the lower.

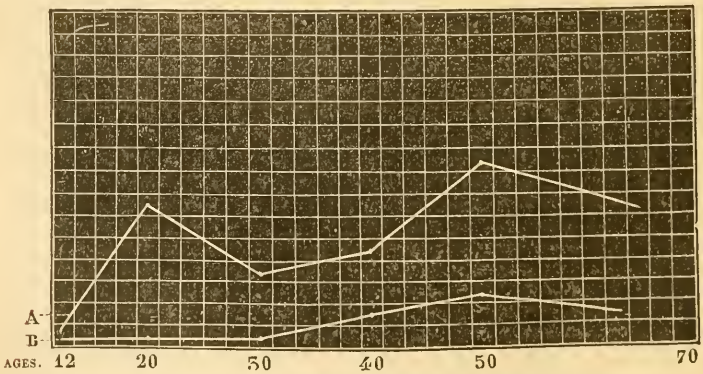



FIG. 4. Tracings representing the Relative Frequency of Dental Caries for each year in the Canines, upper and lower. A. Line of the upper canine. B. Line of the lower canine.

We see in the two preceding curves that the upper canine is much more frequently carious than the lower, and that the maxima for the two teeth corresponding to the age of fifty are in the ratio of three to nine.

If we examine these two lines with reference to the canine considered by itself, we see that they are nearly the lowest of the whole series, corresponding in this respect to the table of cases; our table showing only 515 cases in 10,000. This fact is explained by the very configuration of this tooth, which is singularly unaffected by ordinary causes of alteration. In fact its conical form should exclude the possibility of the lodgment of injurious substances upon its surface.

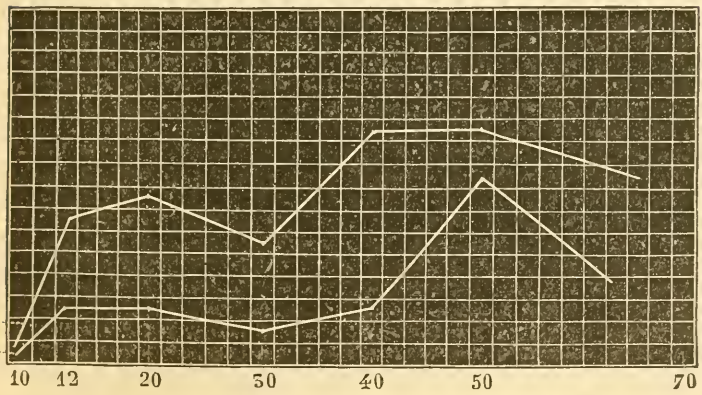



FIG. 5. Tracings representing the Relative Frequency of Dental Caries for each year in the First Bicuspid. A. Line of the upper bicuspid. B. Line of the lower bicuspid.

These two curves, almost parallel, mark a greater frequency of caries in the first upper bicuspid: the two are nowhere far apart, and at fifty years the maxima are in the ratio of nine to eleven. We remark also that the total number of cases of caries in these teeth is already

notably higher than that of any of the foregoing, the table giving 1,310 in 10,000.

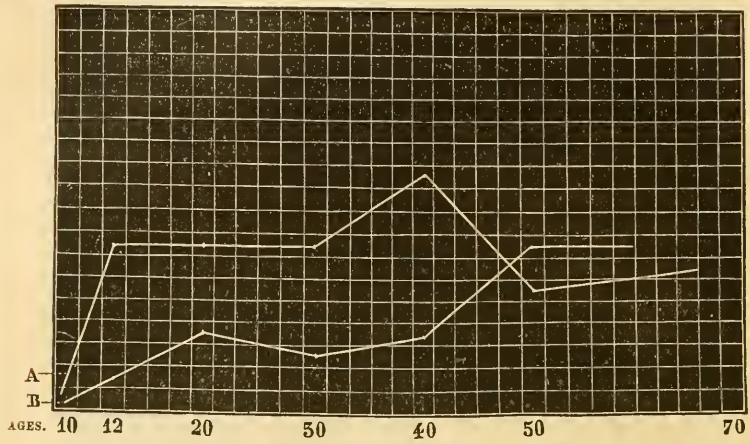



FIG. 6. Tracings representing the Relative Frequency of Dental Caries for each year in the Second Bicuspid. A. Line of the second upper bicuspid. B. Line of the second lower bicuspid.

The examination of these curves shows that up to the age of forty, caries is very markedly more frequent in the upper tooth; but from that age the frequency in this tooth decreases, whilst in the other it increases, attaining its maximum at fifty years.

The next two are evidently the highest of the whole series, a fact in direct relation with the high figure representing this tooth in the foregoing tabular view. Moreover we see that the tracing of the lower molar at about the age of twelve, rises above that of the upper, resulting in a crossing of the lines; afterwards the lines remain nearly parallel, with a constant numerical superiority of the lower molar, and the maxima, corresponding to the age of fifty, are in the ratio of twenty-four to thirty-two.

This inverse relation, observed by us in the two lines of the first molar, is found also in the diagrams of Tomes,

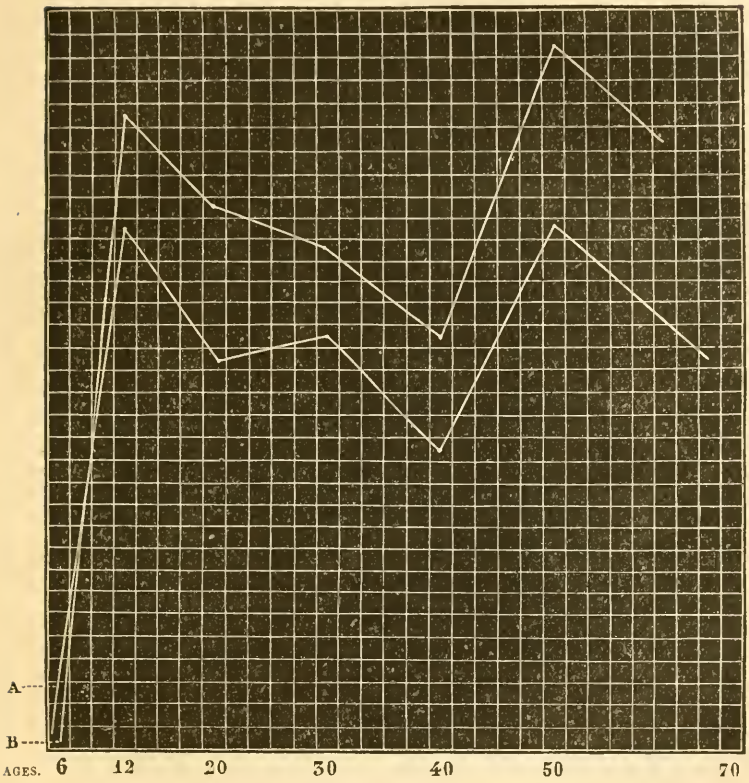



FIG. 7. Tracings representing the Relative Frequency of Dental Caries for each year in the First Molar. A. Line of the upper molar. B. Line of the lower molar.

Sen., who has remarked a still greater predominance of caries of the lower tooth over the upper.

If we now seek to explain the disposition of these two tracings from the point of view, 1st, of their common ele-

vation; 2d, of the crossing of their lines, we reach the following conclusions.

The great frequency of the decay of the first molar is due to various circumstances. We have already shown that this tooth undergoes, during the very long period of its intra-follicular evolution, disturbances of nutrition, drawing after them indelible defects of internal structure. It must be noted, moreover, that at the moment of its eruption, which corresponds to a period of infancy often critical, the health of the patient may frequently be affected by maladies common to that age, whose action upon the dental tissues we will study hereafter. To these causes it must be added that the tooth in question is, of all the permanent series, the first to make its appearance, and is thus exposed, more than all the others, to the various causes of alteration present in the buccal cavity.

As regards the crossing of the lines, establishing this predominance of caries in the lower tooth, we cannot well explain it. The periods of eruption are nearly simultaneous, and the conformation is not sensibly different. We remark, nevertheless, that the under tooth may more frequently present various anatomic predispositions to caries. The inter-tubercular fissures are more marked and deeper, and the external face of the crown especially has a frequent minute depression, well known as a favorite seat for caries.

The two following tracings for the second molar, like the preceding, cross one another, the frequency of caries being greater for the lower than for the upper tooth. The crossing, however, does not occur till the age of thirty, and the two lines attain their maxima at fifty, where the frequency of caries in the upper is to that in the lower tooth as ten to thirteen.

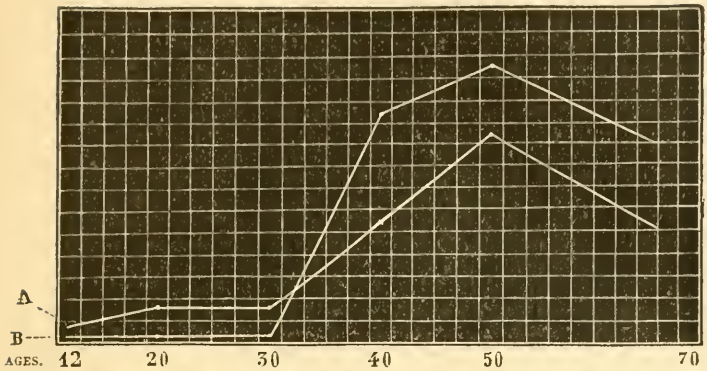



FIG. 8. Tracings representing the Relative Frequency of Dental Caries for each year in the Second Molar. A. Line of the second upper molar. B. Line of the second lower molar.

The examination of the following lines shows that from the moment of the appearance of the wisdom tooth, which

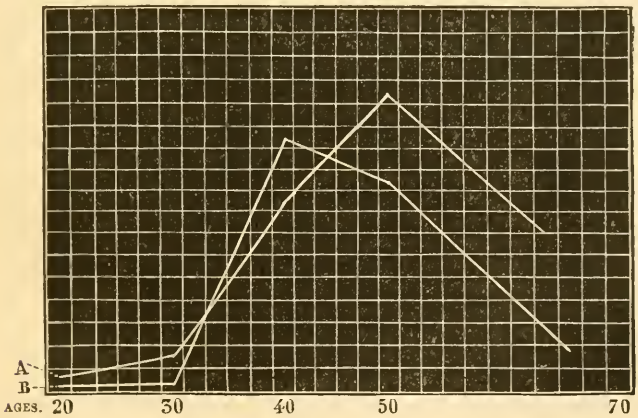



FIG. 9. Tracings representing the Relative Frequency of Dental Caries for each year in the Third Molar, or Wisdom Tooth. A. Line of the third upper molar. B. Line of the third lower molar.

takes place on the average at twenty years, up to thirty years of age caries is almost *nil* in the lower, but more

marked in the upper tooth, whose tracing up to this time is always above the other; that onward from the age of thirty the lines rise rapidly, attaining their maxima at forty years for the lower, and at fifty for the upper tooth.

This *résumé* of statistical data refers, as will be seen, to the permanent dentition. We have, nevertheless, undertaken an analogous task for the temporary teeth, which are likewise subject to caries, at least under our ordinary social conditions. The results of this new inquiry are set forth in the following table: —

*Table indicating the Frequency of Caries in the Temporary Dentition, as shown in One Thousand Cases.*

| | | | | |
|---|---|---|---|---|
| Central incisor | 140 | upper, 123 | right, 64 | |
| | | | left, 59 | |
| | | lower, 17 | right, 8 | |
| | | | left, 9 | |
| Lateral incisor | 180 | upper, 152 | right, 80 | |
| | | | left, 72 | |
| | | lower, 28 | right, 13 | |
| | | | left, 15 | |
| Canine | 87 | upper, 51 | right, 22 | |
| | | | left, 29 | |
| | | lower, 36 | right, 16 | |
| | | | left, 20 | |
| 1st molar | 332 | upper, 124 | right, 66 | |
| | | | left, 58 | |
| | | lower, 208 | right, 110 | |
| | | | left, 98 | |
| 2d molar | 261 | upper, 93 | right, 41 | |
| | | | left, 52 | |
| | | lower, 168 | right, 75 | |
| | | | left, 93 | |
| Total | 1,000 | | 1,000 | 1,000 |

Examining these figures in their relations one to another, we remark certain coincidences which recall the first table of the permanent dentition. Considered as a whole we see that caries in the deciduous period affects

the upper jaw by preference; for in a total of 1,000 cases, 543 are found for this against 457 for the under jaw.

The tooth most frequently attacked is the first molar, then follow successively the second molar, the lateral incisor, the central incisor, and lastly, the canine. For the three last the malady is much more common in the upper jaw, while for the two molars the relation is inverse, dispositions which recall those of the permanent teeth.

As regards the age at which, in the child, the malady appears, without having applied to this the graphic tracings, we are yet able to give some indications; thus it is at about the third or fourth year that we first observe caries, and its frequency increases from this moment in a regularly progressive manner, up to the age of twelve, the average period of the loss of the last deciduous tooth.

The physiognomy and the different characteristics hereinbefore described, size excepted, are moreover completely repeated in the temporary and permanent teeth. For the first the alteration seems to be more rapid, and, in some cases by the fourth or fifth year, may cause the complete destruction of all the crowns, so that at their natural shedding there are lost no longer teeth but shapeless and nearly unrecognizable débris.

As concerns the place of election of caries in a given tooth, the considerations already developed touching the predisposing anatomic conditions, vice of conformation, etc., answer these questions. In a general way, caries never affects at the outset the convex, smooth, and polished parts of the crown; such are the anterior faces of the incisors, the external and internal faces of the bicuspids, the lingual face of the molars. In the cases of accidental caries, that is, caries produced under the influence of a temporary and slightly active cause, it is in a

groove of the crown of a molar, a preëxisting fissure, that the malady appears. These points occupy the first rank in the order of election of caries; then follow the dental interstices which retain for a longer or shorter period collections of substances in which are produced the agents of alteration. In such cases caries is most frequently double, occupying the two contiguous points of the teeth which bound the interstice. Finally, in the order of frequency we name the neck of the teeth, especially affected in cases of caries governed by a general and permanent cause. These take a peculiar form and character, to which we have given in the description of the pathologic anatomy the name of finger-nail caries.[1]

In all cases it is found that caries localizes itself in a tooth at points where alimentary substances, the fluids of the mouth, and other foreign matters, most easily effect a lodgment. Further on we shall develop these considerations, when we treat of the phenomena of disorganization which the malady produces.

The well defined congenital lesions we have just described are not the only anatomic predispositions to caries; there are others of a more general but not less important character; we refer to conditions of dental organization depending upon heredity, race, constitution, and diathesis.

It is notorious that, in certain families and in certain races, caries is a frequent and habitual malady. Now it is impossible to admit the transmissibility in this way of an affection which, as far as we can see, is but a chemical alteration of the tissues, and from these cases of apparently hereditary caries an argument could be made against the doctrine which we defend. This argument

[1] *Coup d'ongle* (scratch of the nail).

is, however, specious, and we must distinguish that, if it is impossible to inherit in the true sense dental caries, that is to say, the cause or the germ of the infection, it is very admissible to allow the transmission of certain anatomic predispositions of structure. This is the true state of the case, and nothing is more remarkable than this analogy of character and conformation of the teeth among the members of the same family, or of a group of persons of the same race. Thus we have proved vicious dispositions of the dentition, anomalies reproducing themselves through several successive generations. On the other hand, we know that certain circumstances of form, of color, and doubtless of intimate structure, constitute ethnological characteristics of certain populations; it is not therefore difficult to admit the community of anatomic predispositions to caries. It is thus that certain bluish white teeth, which owe this color to the defective consistency and lack of homogeneity of their elements, to the diameter of the canalicules and their anastomoses, to the imperfect calcification of their enamel, are almost fatally predestined to caries. The same is the case with teeth which present whitish transverse furrows, alternating with more transparent zones, indicating irregularities in the constitution of the successive layers, while teeth of a milky white, slightly diaphanous or grayish, are generally endowed with a robust and resistant conformation.

These considerations lead us to the so much desired explanation of the endemic caries which from time to time has been attributed to the conditions of the surroundings, the neighborhood of rivers, the use of certain waters,[1] and certain drinks.

[1] Regarding the waters used for drinking, so often invoked empirically in the etiology of dental caries, as in that of many other maladies, we

These various hypotheses cannot be verified, with the exception of the last, and we shall learn further on, by our experiments, the part we may reasonably attribute to acid drinks, cider, for example, in the production of caries among certain populations, as in Normandy, where its use is habitual. Notwithstanding, in this question we will not attribute any such importance to cider, although its destructive action on the teeth is well established, inasmuch as many of the Normands who make no use of it at all show the same predisposition to caries. We therefore believe that the principal cause of the malady in this district is a faulty internal construction of the teeth so general as to constitute a true race characteristic. Moreover heredity in matters of dental caries is not more surprising than in any other physiologic or morbid disposition, and such transmission is a fact perfectly demonstrated. As will be seen further on, we recognize the same character in other dispositions which we consider equally congenital or hereditary, and which go to modify the constitution and the reaction of the salivary liquids.

In order to complete the general data relating to the transmissibility of the predisposing conditions of caries, a comparative examination of the different races of men, or the peoples inhabiting one same region, should be undertaken in this direction, but reliable documents are wanting in this regard, and no element of statistics has yet been promulgated of the relative frequency of caries in the great anthropologic groups. What we do know, nevertheless, is that in a general way the Negro and Arab races are endowed with a dentition relatively beau-

refer the reader to the remarkable essay upon this question read by M. Robinet, at the Academy of Medicine. Vide *Bulletin de l'Académie,* vol. xxx., pp. 83 and 953.

tiful and resistant, if we omit the ethnologic considerations of configuration, direction, and size of these organs; that the Caucasian races appear more particularly liable to caries; and that the Mongol races of the extreme east and of Asia hold nearly the middle place. The mixed races seem more exposed to it than those which have remained comparatively pure, as is also the case with those which have been transplanted away from their native soil, the Creoles, for example, or whose acclimation has been difficult.

Among the ancient aboriginal peoples of Europe, caries appears to have been, at least, as frequent as to-day (Broca), and of all the collections of crania possessed by the Society of Anthropology, as well as of all those which have been furnished us for investigation upon this point, there is no one where caries is as frequent, and the wear of the teeth so marked, as in the collection of eighty Basque crania.

An examination made by us from this point of view, in the anthropologic collections of the Museum of Natural History of Paris, has furnished some general results. The crania of the autochthonous populations of the American continent, Mexico, Peru, Patagonia, etc., have not given us a single example of caries; the same has been the case with those coming from Australia, Madagascar, New Caledonia, etc. The collection of Malay and Javanese crania, of Professor Wrolik, presents no more. These are, on the contrary, remarkable for the perfection and size of the teeth, with very marked wear, and abundant masses of tartar, more or less colored by the use of the bétel and other substances. The crania or skeletons of mummies, or those taken from the very numerous catacombs, have furnished us with a number of

cases of caries quite marked, though difficult to determine in a precise manner, by reason of the more or less damaged condition of many of the specimens; yet we have been able to recognize about a dozen examples in forty crania of the Egyptian epoch. In Europe proper, there are few populations spared by this malady. Nevertheless, the Icelanders, according to recent investigations, seem to be nearly exempt from it.[1]

These general considerations, which in the actual state of science cannot be reduced to figures, need not detain us longer. Yet, if we do not possess exact documentary evidence concerning races in general, at least we have it in the case of one region, that of France.

It is well known that a bad condition of the dental organs constitutes a cause of exemption from military service. Now, at the age of the conscription, the malady which oftenest causes the loss of the teeth is caries. The statistics of the war-office should, therefore, supply us with precious documents, which, though limiting their information to the cases of young men of twenty years of age, may be considered as giving a regular proportion of caries for the whole mass of the population of each department.

Now, the French law exempts from military service, first, when there is a loss or caries of the incisors or canines of one of the jaws; second, when there is a loss, caries, or bad condition of the majority, or of a large number of the other teeth. In an abstract of M. Boudin's,[2] for the period comprehended between 1831 and

[1] *Vid.* Beaugrand, *Annales d'Hygiène*, 1866, vol. xxvi., p. 430; and Le Bret, *Examen Anthropologique des Collections Recueillies dans le Voyage du Prince Napoléon.* (*Arch. Gén. de Médecine.* Paris, 1857.)

[2] *Traité de Géographie et de Statistique Médicale*, Paris, 1857, vol. ii., pp. 431–433.

1849 inclusive, the councils of revision have pronounced exemption for imperfect denture of 25,918 young men, out of 3,295,202 examined, equivalent to an average annually of 785 exemptions in every 100,000 examined. The annual maximum was 895, in 1837 ; the minimum, 643, in 1847. The following table indicates the proportion of exemptions for loss of teeth in the eighty-six departments, during the period from 1837–1849 inclusive, thirteen years, in every 100,000 examined.[1]

*Comparative Table of Exemptions from Military Service for Imperfect Denture, by Departments*, 1837–1849.

| | | | |
|---|---|---|---|
| 1. Puy-de Dôme | 36 | 26. Saône-et-Loire | 251 |
| 2. Haute Loire | 41 | 27. Isère | 254 |
| 3. Finistère | 60 | 28. Hautes Alpes | 255 |
| 4. Rhône | 85 | 29. Aveyron | 265 |
| 5. Cantal | 99 | 30. Vaucluse | 271 |
| 6. Corrèze | 102 | 31. Corse | 274 |
| 7. Loire | 111 | 32. Nièvre | 282 |
| 8. Morbihan | 119 | 33. Cher | 283 |
| 9. Mayenne | 133 | 34. Tarn-et-Garonne | 284 |
| 10. Côtes-du-Nord | 137 | 35. Haute-Saône | 286 |
| 11. Drôme | 139 | 36. Deux-Sèvres | 290 |
| 12. Aude | 146 | 37. Lot | 311 |
| 13. Tarn | 156 | 38. Vosges | 319 |
| 14. Gard | 165 | 39. Jura | 323 |
| 15. Ille-et-Vilaine | 175 | 40. Creuse | 356 |
| 16. Allier | 178 | 41. Manche | 377 |
| 17. Haut-Rhin | 184 | 42. Haute-Vienne | 397 |
| 18. Pyrénées Orientales | 186 | 43. Charente | 404 |
| 19. Ain | 188 | 44. Doubs | 415 |
| 20. Moselle | 194 | 45. Bas-Rhin | 416 |
| 21. Gers | 197 | 46. Haute-Garonne | 424 |
| 22. Hérault | 211 | 47. Sarthe | 462 |
| 23. Meurthe | 215 | 48. Basses-Alpes | 514 |
| 24. Lozère | 221 | 49. Nord | 531 |
| 25. Ardèche | 222 | 50. Seine | 532 |

[1] A. Devot, *Comptes Rendus sur le Recrutement;* Inaugural Thesis, 1855, p. 20.

| | | | |
|---|---|---|---|
| 51. Var | 551 | 69. Basses Pyrénées | 1,003 |
| 52. Marne | 553 | 70. Seine-et-Marne | 1,013 |
| 53. Charente-Inférieure | 557 | 71. Ardennes | 1,061 |
| 54. Ariége | 604 | 72. Lot-et-Garonne | 1,111 |
| 55. Loir-et-Cher | 624 | 73. Hautes Pyrénées | 1,140 |
| 56. Indre | 627 | 74. Eure-et-Loire | 1,269 |
| 57. Loiret | 644 | 75. Orne | 1,537 |
| 58. Vienne | 652 | 76. Somme | 1,727 |
| 59. Côte-d'Or | 674 | 77. Calvados | 1,732 |
| 60. Bouches-du-Rhône | 741 | 78. Landes | 1,819 |
| 61. Meuse | 792 | 79. Gironde | 1,837 |
| 62. Aisne | 814 | 80. Loire-Inférieure | 1,959 |
| 63. Vendée | 831 | 81. Maine-et-Loire | 2,017 |
| 64. Yonne | 834 | 82. Seine-et-Oise | 2,120 |
| 65. Aube | 902 | 83. Oise | 2,623 |
| 66. Haute-Marne | 946 | 84. Seine-Inférieure | 3,140 |
| 67. Pas-de-Calais | 959 | 85. Eure | 5,014 |
| 68. Indre-et-Loire | 1,000 | 86. Dordogne | 6,760 |

We see by this table that loss of teeth, *i. e.*, caries, considered as cause of exemption from military service, is at its minimum in the Puy-de-Dôme; that it attains its maximum in the Dordogne; and, finally, that the minimum is to the maximum as 1 is to 18. Viewing them in their geographical relations the minima of exemptions form two groups, of which one consists of a great part of Brittany, the other, much larger, occupies the central plateau of France, and is prolonged towards the Mediterranean, following the two banks of the Rhône. The maxima, on the other hand, are found solely in the departments of ancient Normandy, at the mouths of the Garonne, the Loire, the Dordogne, the Seine. If now we regard the regions which occupy the extreme points, Brittany and Normandy, we have the following figures, in each 100,000 examined: —

| Brittany. | | Normandy. | |
|---|---|---|---|
| Côtes-du-Nord . . | 137 exempts. | Orne . . . . | 1,537 exempts. |
| Morbihan . . . | 119 " | Calvados . . . | 1,732 " |
| Finistère . . . . | 60 " | Seine-Inférieure . | 3,140 " |
| | | Eure . . . . | 5,014[1] " |

These figures acquire a still higher importance if we consider the relative population of the departments, thus: Finistère, one of those which give the fewest exemptions for imperfect denture, has a total population of 547,000 inhabitants; Eure, one of those which give the most, has 450,000 inhabitants. We have from the totals of these diverse results made out a chart representing their proportions by departments. This chart, by a division into three tints, indicates three distinct artificial series from the point of view of the frequency of dental caries in France. The first series, beginning in the tabular view at the Puy-de-Dôme, and ending with the Aveyron, includes the least affected departments; the second, from the Vaucluse to the Vienne, holds the middle ground, and the third, that of the departments most affected, extends from the Côte-d'Or to the Dordogne.

If we now examine the annexed chart of the distribution of dental caries in France, with the purpose of explaining its physiognomy, we arrive at the following principal conclusions: one fact remarkable at sight is the existence of three great dark regions corresponding to the greatest frequency of caries. The first comprehending the departments of the north, French Flanders, Picardy, Normandy, Champagne; the second, four departments of the west, Anjou, Poitou, the Vendée; the third, the departments of the southwest, Guienne and Gascony,

[1] *Mémoires de la Société d'Anthropologie,* vol. i., p. 144; *Bulletins* of the same Society, vol. ii., p. 666.

Bearn. In contrast, to these three black regions, we remark two others which are entirely white, one formed of the departments of Brittany, the other composing a great central region which extends on one side to the east, towards the Alps, and on another to the south as far as the Mediterranean. Between these extreme tints there are grouped intermediate regions more or less colored, with some spaces clear or dark, representing accidental exceptions.

Now, if, in the explanation of this chart we call to our aid the causes ascertained up to the present day in the etiology of caries, we remark that no one of them by itself can give an explanation covering every particular.

The nature of the drinks used by the populations plays, as we have already hinted, but a secondary rôle, or perhaps is *nil*. Thus in the dark region of the northeast, the use of beer, a fermented alcoholic drink, is habitual; in Normandy, equally darkened, the drink is cider, a fermented acid liquor. But this same drink is used in Brittany, where caries is very rare. As for wine used in the rest of France, we can assign to it no part in the production of caries in presence of the very varied tints presented by the region of the vines.

The course of the rivers has apparently no greater influence. In fact, while the Seine and Garonne water regions very much affected, the Rhône bathes a country exempt, and the Loire, in the first half of its course, waters a white region and in the other half a black one.

The neighborhood of the sea has no greater significance, for if Normandy represents the region most affected, Brittany pushed out into the ocean is at the opposite extremity of the series.

We might pass in review and successively refute the other influences which have been named: the altitudes, the geological basins, the climates, the common alimentation, the conditions of wealth or of poverty, etc., and we should arrive at this result, that no one of these circumstances, taken by itself, can supply the explanation we seek.

What then is the significance of this chart and of its principal characteristics?

We have already remarked upon the influence of race in the question which occupies us, and it seems evident that we must have recourse to considerations of this nature to explain the various tints the chart offers us.

In consulting the documents collected upon the ethnology of France, and particularly the remarkable work of M. Broca,[1] we recognize that the best preserved vestiges of the two principal races that have peopled our soil are represented in our chart by opposite tints. Thus the Celtic race included in the region of Brittany is marked in white; the other white region of the chart is still correspondent with an agglomeration of Gallic peoples, a central Celtic region. On the other hand, if we regard the black trail crossing France from the northeast to the southwest, without taking account of some intermediary tints of no importance, we find that this direction is precisely that followed by the Cymric invasion which entered Gaul about the seventh century before our era and left such lasting traces.[2] Now to the well defined contrasts separating these two races, Celtic and

[1] *Mémoires de la Société d'Anthropologie*, vol. i.

[2] Some Cymric groups quite pure, are still found along this trail; such are the Boiens-de-la-Teste, the Volkes tectosages (Belges) of Toulouse, etc.

Cymric, we think there should be added the circumstance of numerous cases of caries through primitive defects of dental constitution. Other interesting considerations might be suggested by this rapid glance. If our chart is compared with others which have been compiled for various infirmities, as for example, that of M. Broca,[1] for defect of height, we arrive at a singular result. Thus, whilst the departments of Brittany are white upon our chart they are black upon that of M. Broca, and the same inversion is found for the central Celtic region. On the contrary all our black tints which indicate Cymric populations are white in that of M. Broca. This constant opposition of tints conducts us to this conclusion, that the population of France is divided in a general way, in regard to dental caries, into two great families: the Celtic family has small and stocky individuals with a hardy dentition; the Cymric family has large blonde individuals, whose dental organization is defective.

We will not enlarge further upon these considerations, which are still necessarily limited by the actual state of anthropological science. But we think it has been clearly shown that, in the explanations of endemic caries, account should be taken of questions of race still more than of the diverse conditions of soil and surroundings.

The anatomic predispositions of dental caries transmissible by heredity, may, as we see, constitute a normal fact, without relation to one or another morbid state, the subjects presenting, moreover, the ordinary conditions of stature, form, and beauty. Caries is then a perfectly isolated and local affection. But this is not constantly the case, and we shall now have to take account of the

[1] Broca, *Mém. cit.*, chart, p. 56, and two unedited charts by the same author, for exemption for defective height in the periods 1831–1849 and 1850–1854.

influences exercised by constitutions and diatheses in the production of the general defects of the dental organ. In a general way, and aside from the question of race, a robust constitution implies the perfection of every part of the organization, consequently of the teeth, and still further of their energetic resistance to the agents of caries and their persistent integrity; whilst a feeble constitution predisposes in every way to this kind of alterations. It is not necessary for us here to recur to the intimate causes of these differences; they have been hereinbefore developed: the external form of the teeth, the continuity and smoothness of the superficial contours, every appearance, in fine, may be the same, and yet the structure may vary interiorly from one extreme of the constitution to the other. The temperaments have an analogous effect; thus, the sanguine and nervous seem less subject to caries, whilst the lymphatic and bilious are disposed to it. Finally, the chronic maladies and the diatheses, otherwise than as they excite, as we shall see hereafter, the production in the saliva of agents peculiarly active in causing caries, may, if they govern the organization of a patient during the phases of the dental evolution, become the causes of disturbances in these phenomena. Such is rachitis, which produces diminution of volume in the teeth, their habitual pale and transparent tint, and their delicate texture. The same is the case with the tuberculous, rheumatic, syphilitic, etc., diatheses. The last produces especially disastrous effects upon the teeth, and we see in infants affected with hereditary syphilis small, deformed teeth with deep fissures, whose enamel and ivory, imperfectly calcified, are permeated with opaque spots and remain weak and brittle.[1]

[1] See Hutchinson's *Ophthalmic Hospital Reports*, Nos. 4 and 5, pl. cxci.

Dental caries being capable of production at every age of life, the temporary and permanent teeth are equally subject to it. Moreover the various causes which produce it will have a greater hold upon the tissues in proportion as the tooth shall have taken less time in its eruption. In fact, a tooth at the moment of its appearance has not the resistance and the compactness it will subsequently acquire, and caries at this epoch will invade it more easily. Another circumstance which should here be noticed in reference to the first dentition, is the rôle of pregnancy. It has been seen that the permanent teeth may feel the influence of the various affections and conditions of infancy, during which period their evolution is accomplished. As regards the first dentition, which originates as we know at the second month after conception, it is the condition of the mother, the diverse accidents or phenomena of gestation which govern the qualities of texture and internal organization of the teeth during the whole time of the intra-uterine life. From this it results that, all conditions being equal in other respects, if the pregnancy has been regular and normal, the first dentition will be correct and strong; but if it has been troubled and interrupted by morbid disturbances of any kind, the teeth will present, to a certain degree, the local or general defects we have described for the permanent teeth, and consequently all the predispositions to caries which belong to these. We understand from this how the temporary teeth, already smitten with defects of internal quality, fall so easily under the influence of destructive agencies.

B. Acquired Anatomic Conditions. The accidental anatomic conditions which may predispose to caries are traumatic lesions modifying the structure of the

dental tissues, such as cracks, fractures, wear, and luxation. The cracks which belong especially to the enamel, occur either from external violence, or a sudden transition in the temperature of the mouth. The frequency of these cracks is such that it is difficult to find an adult tooth that does not contain one or more of them in its enamel covering. Yet, in the absence of any efficient cause, cracks scarcely penetrable by the fluids, and which are perceived only after drying or in section under a microscope, have no signification nor importance; but when they are larger and permeable they may play the exact part which we have recognized in the congenital fissures or crevices. On the other hand, if the cracks are situated at a point otherwise favorable to chemical action, as in a dental interstice, and if this action takes place with sufficient energy, caries may at once be formed. There is a species of wear or of disaggregation resulting from the contact and vibrations of two contiguous teeth during the movements of the jaws and the acts of mastication. There is thus produced upon opposite points of two teeth, crowded one against the other, a sort of dissociation of the enamel prisms, followed by the formation of a minute depression, or of an opening penetrating the enamel layer to a varying depth and often reaching even to the dentine. This fact goes to explain the predilection of caries for the position in the dental interstices.

The *fractures* — and by this term we mean the partial fractures which do not penetrate the pulp cavity, but deprive the crown of a portion of greater or less extent of its layers of enamel and ivory — uncover the internal parts which are consequently less dense, and more accessible to chemical action. It is thus that we often see caries attack the point of a tooth anteriorly fractured. If the loss of substance has trenched upon the cavity of the

pulp and occasioned the loss of that organ, the development of the malady is still more prompt, for the destructive agents shut up and localized in a natural cavity acquire there great energy.

The *wear* of the teeth is a normal and permanent phenomenon, which results from the relative disposition and mode of occlusion of the two dental arches, being more pronounced in proportion as this occlusion is more immediate and vertical. To this the incisors owe the disappearance of the denticulations they possess at their eruption, and the molars, the gradual effacement of their tubercles. This phenomenon, slow and progressive, continues during life, and has for its effect the constantly increasing reduction of the height of the teeth, causing in time the complete disappearance of the crown enamel and penetrating some distance into the tissue of the ivory.

This wear varies greatly according to the mode of alimentation, and ethnological researches among the craniæ of primitive epochs appear to have established that it was then more pronounced by reason, perhaps, of the uncooked food then commonly used.[1]

The influence of this wear of the teeth upon dental caries is the same as that of other circumstances which uncover the ivory by depriving the tooth of its protection of enamel. Yet, it must be said that this phenomenon, happening for the most part only in the aged, is counterbalanced by the augmentation of density and resistance which the dental tissues have acquired by the incessant molecular modifications they undergo. On the other hand, the worn surfaces being polished and slippery offer very slight opportunity for chemical action, so

[1] See Garrigou, *Bulletins de la Société d'Anthropologie*, 1864, p. 939.

Perhaps from the grit worn off from the stone mortars in which they bruised their grains. — Tr.

that, in fine, caries developed upon the points of wear in the adult and the aged are comparatively rare.

Another kind of wear to which we should refer is that which may be caused by clasps or bands applied to the teeth on apparatus for regulating them, or for sustaining plates bearing artificial teeth. This has the greater importance in that it may happen even in young patients. Thus we often see the change have its origin at the bottom of the gutter or depression caused by a metal or other band.

Complete or incomplete *luxations* of the teeth followed by consolidation, have a predisposing influence upon the development of caries resulting from disturbance in the nutrition of the organ. In fact it is frequently observed that, following upon consolidation after luxation, the pulp of the tooth has undergone mortification and consequently the extinguishment of its functions, and therefore cannot offer any resistance to the attacks of caries. The tooth then becomes of a brown or black color, and caries, when developed, progresses in it much more rapidly, taking on at the same time the dark tinge that results from the penetration of the dental canalicules by the mortified elements of the central pulp.

### § 2. *Of the Saliva and its Modifications.*

We propose to demonstrate under this heading, that the saliva is the veritable agent of caries, not indeed by its original constitution, unfitted of itself to exercise any action on the teeth, but in consequence of the infinite variations its composition undergoes under diverse influences, which we shall examine; variations resulting either from the spontaneous development of substances endued with an altering action upon the dental tissues,

or from the accidental introduction of these same substances, already formed, from without. We are thus led to study: A, the normal saliva; B, its accidental and morbid changes.

A. Normal Saliva. — The saliva from our point of view should be regarded under two successive aspects: 1st. The salivary secretions properly so called, or simple salivas. 2d. The mixed saliva, composed of the union of these latter in the buccal cavity with the different products of the mucous membrane. The simple salivas are the following: —

1st. The *parotid saliva*, a watery fluid, of a density of 1,006, absolutely without viscosity, alkaline, and holding in solution substances which upon cooling and at rest, form a deposit of a whitish color, which we recognize as formed of carbonate of lime, crystallized in rhombohedral forms, and mingled or combined with a certain proportion of organic matter. When treated with acids it gives out carbonic acid gas. This peculiarity serves to explain the deposits, at times so abundant, of tartar upon the upper molars, particularly on the external face in the neighborhood of the duct of Steno, especially when from any circumstance the opposite side is not used. This fluid, constantly alkaline, according to Cl. Bernard,[1] has been sometimes found acid by M. Mitscherlich, in man, upon the margins of a parotidian fistula, where the fluid dripped in minute quantity, to become alkaline again when it poured forth in abundance. This fact, nevertheless, does not prove that the parotid saliva can be acid, the reaction in the experiment of which he speaks being due doubtless to the presence of the perspiration or of

[1] *Leçons de Physiologie Expérimentale*, 1856, vol. ii., p. 62.

some product of fermentation upon the cutaneous margins of the fistula.

This saliva contains on the average from 95 to 98 parts in 100 of water, against 2 to 5 of solid substances which are chiefly carbonates of lime, either free, or according to Lehman,[1] combined with organic matters. This organic matter, common, excepting some secondary differences, to the different kinds of saliva, and which has been named by Berzelius *ptyaline*, is coagulable and exists in the saliva of the parotid only in a very minute quantity. We find also the chloride of potassium, bicarbonate of lime, a little phosphate of lime, and finally sulpho-cyanide of potassium, which has been recognized by some authors.

Variations may occur in the secretion from the parotid, as in that of the other salivary glands. We know that the parotids secrete alternately, and that their saliva is the only one which is produced without the stimulus of food; therefore, diet has less influence upon its secretion than upon that of the others. The presence of dry food in the mouth seems especially to excite it, and its expulsion depends upon the compression, exercised upon the gland by the muscles of the parotid region in the movements of mastication.

The experiments of Cl. Bernard[2] have, moreover, proved that this gland is under the influence of the trigeminal and facial nerves, which explains why neuralgias of the fifth pair, and the diseases of the teeth, sometimes excite an abundant flow of saliva, due, doubtless, in great part to a hypersecretion of the parotidian fluid.

2d. The *submaxillary saliva*, a limpid liquid, but very viscous, a quality which, under the influence of cold, gives it an almost gelatinous consistence. It does not, as

[1] *Lehrbuch der Phys. Chemie*, vol. ii. [2] *Loc. cit.*, p. 69.

the former, deposit crystals of carbonate of lime, but, nevertheless, its reaction is clearly alkaline. It contains, according to the analyses of Bidder and Schmidt, about 3 in 100 parts of organic, and 5 in 100 of inorganic matter, and does not contain any sulpho-cyanide of potassium. The secretion of the submaxillary gland is intimately connected with the phenomenon of gustation, and may be excited by a reflex action of the nerve of taste, a lingual branch of the fifth pair among some nervous filaments, which, according to Cl. Bernard, may belong to the branches of the chorda tympani. These peculiarities which give to the submaxillary gland a special character, explain how fasting and dieting may cause the almost absolute suppression of the secretion.

3d. The *sublingual saliva*, isolated for the first time by Cl. Bernard,[1] is a transparent alkaline liquid, extremely viscous, owing, like the preceding, to the presence of coagulable and ropy organic matter, the ptyaline of Berzelius, and considered for a long time as a special salivary ferment. We may liken the sublingual saliva to the liquid produced by the accessory gland of the duct of Steno, or *accessory parotid*, which secretes a saliva having the same characteristics.

4th. To the simple salivas just mentioned, we must add the product of the secretion of the different buccal glands, so numerous under the mucous membrane, which have been improperly denominated *muciparous glands*. These little glands do not secrete mucus, which is produced by a phenomenon to be explained further on, but a veritable salivary liquid, varying with the points of the mouth occupied by the different groups of these glandules. Thus, those of the palatal curtain and the

[1] *Arch. Génér. de Méd.*, 1847.

palatal vault give out a saliva nearly like the sublingual; those of the interior surfaces of the lips and cheeks pour out a liquid resembling the saliva of the parotid.

Finally, to these salivary liquids, properly so-called, is added a last product of the buccal secretion, the *mucus*, whose relative quantity varies infinitely, according to the individual or the circumstances, and whose mode of formation and especial rôle we will examine further on.

The mixed saliva,[1] that is, the buccal liquid resulting from the mixture of the various secretions poured into the mouth, is, in man, a frothy, clouded liquid, which at rest, separates into three portions: first, at the top, a liquid frothy and ropy, more or less abundant; second, a middle portion, clear, limpid, and less viscous; third, the lowest portion, under the form of a grayish white deposit, in which microscopical examination shows cells of the buccal epithelium in great quantity, fatty globules, leucocytes, or mucous globules, detritus of food, crystals of carbonate of lime, vibrios and cryptogamous bodies, coincident with the alteration of particles of food remaining among the teeth. Some of these are only accidental, and should not be considered as constituent elements of any special saliva.

The reaction of the mixed saliva is, according to most authors, normally alkaline, owing to the tribasic phosphate of soda it contains, but may vary according to circumstances. Our observations in this examination of the reaction of the saliva, have led us to make a distinction between the reaction observed in the mucous membrane of the tongue and of the cheeks, which is really alkaline, and that of the surfaces of the teeth and gums, which is

[1] Cl. Bernard, *Mém. sur les Salives,* and *Comptes Rendus,* and *Mém. de la Soc. de Biol.,* 1852, p. 349.

frequently acid. We have often found this to be the case in patients free from every abnormal condition of the mouth, or of the general health, and it has appeared to coincide with two principal circumstances: the great viscosity of the saliva, and the existence of thick layers of mucus upon the teeth. Now this viscosity being due to the presence of the coagulable albuminoid matter, or ptyaline, this latter is susceptible, by its very nature, of becoming the agent of various fermentations with acid products, at the expense of the alimentary matter retained at the surface of the teeth and in their interstices by the mucus itself that surrounds them. These circumstances coexist also with cases of caries, whose number or gravity seems proportional to this viscosity and this predominance of mucus.

It is therefore a fact perfectly demonstrated by us that the saliva observed in the gingivo-labial groove may be normally acid, even during the whole life. So that, admitting, *a priori*, the consequence of this state upon these teeth, their destruction ought to begin immediately upon the completion of their eruption, as really happens in some patients whose teeth are from infancy attacked by this disease.

This acid reaction peculiar to the gingivo-labial groove in the normal state had been likewise ascertained by M. F. Boudet,[1] who ascertained moreover that it was especially marked in the neighborhood of the upper incisors, while on the gums of the under jaw the unceasing flow of saliva neutralized this reaction. This circumstance, verified by us, also explains why it is that the lower incisors habitually escape caries, while it preferably affects the upper. Two reactions may then be observed in the

[1] *Jour. de Phys. et Chim.*, May, 1842.

saliva in contact with the teeth in the normal state. In a great number of cases this reaction is alkaline as in all the remaining extent of the mucous membrane, and the teeth ordinarily preserve a complete integrity; in other circumstances this reaction is acid, and this fact, which draws with it the consequence of the production of numerous cases of caries, seems to be normal and habitual in some subjects, susceptible of extending to members of the same family, and transmissible by heredity in the same manner as any other predispositions. The various elements composing the mixed normal saliva have then a primitive alkaline reaction, and the acid condition must come exclusively from the fact of certain changes or fermentations, not indeed of these elements themselves, but of foreign substances introduced accidentally, or by the alimentation, and which in this manner give rise to acid products. Now, whilst the predominance in the salivary liquid of mucus and coagulable material may greatly favor the production of fermentation, and consequently the appearance of caries, their small proportion in other cases, added to excess of alkalinity of the saliva, may oppose these fermentations or neutralize their effects.

The saliva has a faint nauseating odor, which has nothing in common with the odors proper to the mouth itself, resulting from the giving off of gases due to the phenomena of putrefaction of alimentary matter, or to those which carious cavities may produce. Left to itself in a vessel freely exposed to the air, at the end of some days the saliva takes on a change of a putrid nature, but fermentation, properly so called, develops there only at the expense of alimentary substances held in solution or in suspension in its interior. The experiments of Cl. Bernard have clearly established that the different salivas,

when isolated, cannot transform into dextrine a solution of starch, in spite of the presence of the coagulable substance, or pretended ferment they contain, and when, in the mouth, there begins a fermentation of amylaceous substances, this result will be owing to the intervention of foreign matters capable of filling at a given moment the active rôle of a ferment. These considerations lead us to regard the physiologic action of the saliva in the business of salivation and deglutition as purely mechanical. A mass of food being introduced into the mouth, the parotid saliva, excited by the contact of food and the movement of the jaws, moistens and penetrates it until the development of their sapid qualities calls out the secretions of the sublingual and submaxillary, whose viscosity can have no other effect than to facilitate the sliding of the alimentary bolus into the pharynx and œsophagus. The phenomenon of amylaceous fermentation should therefore be considered as exceptional in the saliva, and if, at the end of a repast, it partially occurs, it is because the saliva left to itself has after awhile become the seat of certain acts of transformation under the influence of foreign substances able to act as ferments; but it soon ceases entirely after the passage of the first alimentary bolus, and the saliva afterwards keeps to the sole mechanical duty normally devolving upon it.

We find in the composition of the saliva the following elements: —

1st. *Water.* The proportion of water contained in mixed saliva varies in the analyses of Berzelius, Simon, Tiedmann & Gmelin, Bidder & Schmidt, etc., from 992 to 995 in 1000 parts, reducing thus from 5 to 8 the proportion of solid matters, organic and inorganic. According to Lhéritier, the proportion of water is greater in

infants. It increases also in some diseases, as chlorosis, and diminishes in others, the phlegmasiæ. This liquid, in the saliva as in all the other humors of the economy, is not free but in a condition of combination with the organic matter itself.

2d. *Organic Matter.* The organic matters found in the mixed saliva, are, —

*a.* Albumen.

*b.* Caseine.

*c.* Epithelial cells.

*d.* Fatty matter.

*e.* Mucus.

*f.* A special organic substance.

*g.* Vegetable and animal parasites.

*h.* Various substances forming spots or deposits on the teeth.

The presence of *albumen*, contested by some, asserted by others, has seemed to be clearly demonstrated by Cl. Bernard. This fact has no important significancy for the matter with which we are occupied, and the same is the case with *caséine*.

The *epithelial cells* characterize the mixed or buccal saliva, for the examination of the different salivas obtained directly from the ducts does not discover them. We must therefore consider them as elements detached from the buccal membranes. Certain leucocytes are in the same category, and arise from phenomena of irritation so frequent in the mouth. These leucocytes, if we observe them particularly in the whitish collections of the dental interstices, appear swollen and granulous, as they ordinarily are after having been submitted to the action of a diluted acid, a fact in relation with this acid reaction so common about the teeth.

The *fatty matters* contained in the saliva show themselves under the microscope in the form of minute drops or globules of oil, and without doubt come from the food. Certain reactions of these matters have caused the assertion, by Tiedmann and Gmelin,[1] that they contained phosphorus.

The *buccal mucus* upon whose constitution authors are far from agreeing, must arrest us for awhile. It composes, according to Berzelius,[2] one half of the dry residue of the saliva; its reactions have been variously interpreted.

An experiment of Cl. Bernard's[3] upon a dog whose salivary ducts had been divided, has shown that the buccal mucous membrane, covered solely with its product, retained the alkaline reaction. The mucus is then alkaline on the surface of the mucous membrane of the cheeks and of the tongue; but it is not always so at the necks of the teeth and in the dental interstices. In a series of observations made by us in man, the mucus which covers the teeth and gums, tested with litmus paper slightly moistened with distilled water, has been frequently found to be acid, even in a state of health, but more especially in the course of certain acute or chronic diseases with abstinence and diminution or suppression of the salivary secretion. It is then proved by us that if the simple salivas are invariably alkaline, the buccal mucus in the neighborhood of the teeth may accidentally acquire an acid reaction. Now the flow of mucus, almost wanting in some persons, is very abundant in others, and this latter circumstance has always seemed

[1] *Recherches sur la Digestion*, vol. i., p. 11.
[2] *Traité de Chimie*, p. 157.
[3] *Leçons de Physiologie*, vol. ii., p. 121, 1856.

to us to coincide with many carious cavities and a rapid progress of the disease. We will also remark that, in accordance with our observations, the predominance of mucus seems to exclude the presence of deposits of tartar at the surface of the teeth in its favorite positions, and this remark, which we have often repeated, permits us to recognize at first sight the ordinary reaction of the mucus in the neighborhood of the teeth. If the mucus is abundant and the saliva viscous, the surroundings of the teeth will be acid and the tartar scarce or entirely wanting, this substance being dissolved as soon as formed; but there should be found in such mouths more or less numerous cases of caries of a whitish color, soft, and of rapid progress. If, on the other hand, the mucous deposit is entirely wanting, we shall find there a local alkaline reaction, the presence of tartar in great abundance with its consequences upon the gingival border, and a relatively smaller number of caries, or their complete absence. Between the two extremes there is a series of degrees which approach nearer or less near a neutral reaction, the point where in theory are found the conditions of absolute integrity of the teeth and gums.

There may also be observed simultaneously in the same mouth a reaction here alkaline, there acid. In fact, it is common to see the upper gingival mucus acid, with caries of the corresponding incisors, while that found in the lower jaw is alkaline, with chalky deposits and an absolute absence of caries. It is then, we repeat, of the highest importance to distinguish, in the study of the conditions of the saliva, the constant alkaline reaction of the general mucous membrane and that proper to the gingival, which may, according to individuals or circumstances, be acid, alkaline, or neutral.

The buccal mucus, which was formerly thought to be the product of special glands, *muciparous glands*, is, like the mucus of every portion of the economy, the result of a direct secretion from the membrane and its epithelium in the entire absence of glandular organs.

The surface of the chorion of the mucous membrane contains in its interstices glandular orifices, and furnishes the materials for the production of mucus to the epithelial elements, which elaborate them and determine their composition, so that the mucus is in reality a sort of epithelial exudation.[1]

This substance, so formed, presents every characteristic common to the general mucus, containing a special principle *mucosine*, an albuminoid substance not miscible with water, and heavier. This buccal mucus, as well as that of the nose and intestines, may become under certain circumstances hardened; there are then formed in the mouth masses more or less dense, crusts or coatings which are deposited on the surface of the tongue, the gums, and the teeth, during the period of certain febrile diseases, for example. These concrete masses play, as we shall see hereafter, an important part in the production of caries in acute affections, phlegmasiæ, etc.

The *organic matter* peculiar to the saliva, very difficult to isolate, and which had been first observed in the mixed saliva before the discoveries of Cl. Bernard, is an albuminoid substance differing essentially from albumen proper, called by authors *ptyaline*, and showing some variations in its reaction, according as the simple salivas differ. Thus, in the parotid saliva, this substance is coagulable by warmth, by nitric acid, and by the sulphate

[1] See Littré and Ch. Robin, *Dictionnaire de Médecine*, 12th edition, art. *Mucus* and *Sécrétion*.

of magnesia, which do not coagulate albumen; in the submaxillary saliva this ptyaline does not coagulate either by heat or by nitric acid; in the sublingual saliva it is so viscous that it is with difficulty its density can be ascertained by the areometer, and it is not clouded by exposure to the air, contrary to that of the other salivas.

This special organic matter is formed in the epithelial cells that cover the glandular follicles, and its secretion continues for a certain time, even after death. Moreover, it may be extracted directly by pressure upon the glandular tissue itself, when removed from the body, or by making an infusion of this tissue. We are thus enabled to collect it and to observe its peculiarities, as found in the different glands.

Modern investigations permit us to consider this substance as peculiar to the various simple salivas in which it figures in varying proportions, exhibiting properties resembling those of the albumen, but not susceptible of playing the part of a ferment, since, as we have already remarked, the sublingual and submaxillary salivas which owe to it their viscosity, are unable to produce any fermentation in starch. Nevertheless, if, in accordance with the most recent ideas, we ought not to grant to the saliva in the digestive acts any part as a solvent of amylaceous substances, we should not refuse to ptyaline a portion of the influence, exerted by every other analogous albuminoid substance, in the fermentative acts produced in the interior of the mouth by long contact in the dental interstices, the furrows and congenital fissures of the teeth, and the cavities of preëxistent caries.

The *vegetable and animal parasites* contained in the saliva come from interdental deposits or from the gingival

border. If, in fact, we place upon a slide for microscopical examination a small quantity of the whitish, cheesy mass that covers the surface of the teeth in the morning before breaking fast, we find in it the following peculiarities: —

The greatest part of the mass is represented by an innumerable quantity of very delicate filaments, entangled in every direction, and, in certain points where they are found isolated, presenting short subdivisions. These filaments have all the characteristics of a vegetable parasite, of the species of algæ, *leptothrix buccalis*, already mentioned (Plate II., Fig. 8). To this vegetable parasite is sometimes added another species resembling the *oïdium* of thrush, but in less quantity. Animal parasites are also found in considerable number, — the vibrios, *vibrio lineola;* then, in addition, we find epithelial cells of the mouth, fatty globules from the food, minute, irregular bodies presenting every characteristic of phosphate of lime, and which represent fragments of tartar, some leucocytes, various alimentary débris, and, finally, a comparatively large quantity of amorphous granulations, collected in irregular masses in the interstices of filaments of cryptogamiæ, colored green, brown, or black. These granulations, coming, doubtless, from the food, are what form the variously colored, generally greenish or brown, layers that cover the surface of the teeth. These stains, to which we might be tempted to attribute some part in the decay of the teeth, have really no importance. They exist, moreover, in many kinds of animals, the dog, the cat, the horse, the ruminants; they are very abundant, especially in the last, where they form green crusts, sometimes covering almost the whole height of the crown, formed from the vegetable coloring matter of their food.

Other spots are sometimes seen absolutely black, especially frequent on the teeth of smokers, and composed simply of fine particles of carbon.

As for the vegetable and animal parasites, whose presence we also recognize in the cavities of caries in progress, their development appears to us allied to the general phenomena of buccal fermentation. We know the part which M. Pasteur attributes to certain microphytes and microzoa, in his theory of fermentation, and, whether we consider the phenomena as the result of physiologic acts of these inferior beings, or whether we regard the production of these existences, as we are disposed to think, as a result of these very fermentations, the conditions of the mouth may afford grounds for either hypothesis.

3d. *Inorganic Substances.* The inorganic substances found normally in the mixed saliva, are, —

*a*. Alkaline carbonates.
*b*. Earthy phosphates.
*c*. Chlorides.
*d*. Sulphates and lactates.
*e*. Sulpho-cyanide of potassium.

The *alkaline carbonates* arise principally from the saliva of the parotids, which contains a much greater quantity of them than the other glands. A fact worthy of remark, is that the mixed saliva contains proportionally less of it than that of the parotids. Cl. Bernard[1] gives the following explanation of this: The pure salivas, on coming into the mouth and into contact with the air and with the buccal membrane, undergo a sort of decomposition which determines the precipitation of the insoluble carbonates. It is this fact which contributes, in our

[1] *Leçons de Physiologie*, p. 132.

opinion, to the deposits of tartar, whose exact mode of production we are about to explain. The *phosphates* remarked in the mixed saliva are chiefly phosphates of lime and of soda, which form almost the whole mass of the salivary calculi.

The *tartar* is a concrete, stone-like mass, ordinarily of a yellowish shade, or variously colored, capable of becoming at times very hard, deposited upon the surfaces of the teeth. The points where it is especially observed are, in order of frequency, the posterior faces of the antero-inferior teeth, situated in the vicinage of the orifices of the ducts of the submaxillary and sublingual glands; the external faces of the superior molars, near the orifices of Steno's ducts; next, the inferior molars. It is very rarely deposited on the lingual faces of the molars of the two jaws, and is rarely met with on the posterior faces of the antero-superior teeth, which are not bathed by the saliva. These deposits of tartar which, when abundant, become indices of an habitual alkaline reaction of the saliva, may, at times, be formed in considerable masses, especially when, from any cause, the teeth of one side of the mouth take no part in mastication, which has become exclusive on the opposite side. We have seen deposits of tartar so abundant that they surrounded on every side a series of teeth buried in the midst of the mass. It is to this phenomenon that the stories of Pliny and other ancient authors should be referred, who relate cases of teeth united, and forming in appearance one single semicircular tooth for each jaw.

The tartar is composed principally of mineral matter, earthy phosphates, and carbonates, whose relative proportion is very variable, according to different analyses (Berzelius, Vauquelin, Bibra). Thus, there are some-

times found 60 parts in 100 of phosphates, at others nearly the same proportion of carbonates. These differences in the results obtained are easily explained. If the tartar analyzed has been collected from the superior molars, which are covered with deposits chiefly from the parotid saliva, there will be a predominance of carbonates, as in this liquid itself. If it has been taken from the posterior face of the inferior incisors, it will be rich in phosphates. These variations of chemical composition, moreover, are found in the constitution of salivary calculi, and are explained in the same way.

The salts, carbonates, or phosphates, are, in the tartar, mixed and united with a certain proportion of organic matter, epithelial cells, fatty globules, leucocytes, filiform algæ, and infusoriæ of the genera *vibrio* and *monad*.

Of the formation of tartar, various hypotheses have been advanced. M. Serres has asserted the existence of tartaric glands lying in the thickness of the gums, and having the property of secreting the tartar of the teeth. Anatomic observation has not demonstrated the existence of these glands. Cl. Bernard [1] gives as probable an explanation, which makes the formation of the tartar depend upon an irritation of the alveolo-dental periosteum, consequent upon laying bare the gums softened by alimentary fragments, during the acts of mastication. He compares this abnormal secretion to that which sometimes accompanies periostitis of the bones. This explanation cannot be admitted, and besides the fact that there cannot be attributed to the dental periosteum any secretory action, it will suffice to cause its rejection to remark that deposits of tartar are shown upon foreign bodies retained in the mouth, such as the plates of arti-

[1] *Leçons de Physiologie*, p. 134.

ficial teeth, in the entire absence of the natural teeth, and, consequently, of the dental periosteum.

A third theory is that of M. Dumas, who finds in the mouth two kinds of saliva, one acid, the other alkaline, which supersaturates the former. The acid saliva holds the phosphates in solution, and when it shall have become supersaturated by the second alkaline saliva both are precipitated.

This theory does not appear to us at all in conformity with the truth. In our opinion, the tartar results from a simple deposit by precipitation of the earthy carbonates and phosphates, held in solution in the saliva by favor of the organic matter with which they are combined. At their arrival in the buccal cavity, the principles separating upon contact with the air and with the mucous membrane, the salts insoluble in water are precipitated and deposited upon the surfaces of the teeth.

The quantity of tartar found in the mouth varies infinitely in different subjects, and by our theory these differences are easily explained. In fact, on the one hand the simple salivas may contain in certain individuals a smaller proportion of earthy salts in solution, when the tartarous deposit will be relatively scant; on the other hand, the deposit, as it is precipitated on the surface of the teeth, may encounter an accidental acid reaction which neutralizes it and causes it again to enter the saliva in solution; and if, finally, the deposit, already small, is surrounded by an acid medium of great energy, in contact with the teeth and in spite of the neutralization of the formed tartar there still exists an acid reaction which entails disastrous effects upon these organs.

The existence or absence of tartar in the mouth has, therefore, a certain signification in the history of dental

caries; very abundant, it indicates a clearly alkaline reaction of the saliva, as well as of the special region of the teeth, and excludes caries from this region; absolutely wanting, it implies necessarily an acid condition of the surroundings of the teeth, with all its consequences upon the state of these organs. Between these two extreme conditions there are various degrees, with more or less alkaline or acid predominance and the varied results arising therefrom.

To this theory of the formation of tartar may be objected the great disproportion, often observed, of mineral phosphates, which may be almost wanting in the saliva, while the tartar contains of them about 60 in 100. That this objection is not well founded is seen if we reflect that the quantity of saliva secreted, on an average, in forty-eight hours in man, is about 400 grams, so that, however small may be the quantity of phosphates contained in the salivary liquids, the formation of the tartar is still explicable, for we know that this deposit is produced with extreme slowness, and that several years are often required to form a layer of any thickness.

The *alkaline chlorides* are met in notable proportion in the mixed saliva of man. From the point of view which now occupies us they present no particular interest; and the same is the case with the *sulphates*. The *lactates* are nearly in the same category; nevertheless we believe that their presence in the saliva is not normal but accidental, and arises from lactic fermentations, of which the saliva is the medium. As for the *sulpho-cyanide of potassium*, by turns asserted and denied by authors, its production must be connected, if we give credence to Eberle,[1] with a particular state of the nervous system,

[1] *Physiologie der Verdauung.*

and under certain circumstances may become the virulent agent of anger.

B. Accidental and Pathologic Modifications of the Saliva. — Having now considered the saliva in its normal characteristics and physiologic reactions, we proceed to examine the modifications of its constitution and secretion which it may present either accidentally, through the intervention of divers foreign substances, or pathologically, under the influence of certain morbid conditions.

1. *Accidental Modifications of the Saliva.* — The changes of composition which may occur in the buccal liquids in an accidental way are of two orders; they may depend upon the presence of fermentable substances whose active products happen to predominate in the saliva, or arise from the introduction into the mouth of substances whose action is direct, or whose composition is fixed. In these two cases we shall examine those agents only that have the power of attacking chemically the dental tissues with which they are brought into contact, limiting this inquiry to our subject.

(*a.*) Salivary Fermentations. By fermentation in general are understood certain metamorphoses which the proximate principles of vegetable and animal life are susceptible of undergoing under determinate conditions, either by contact with living tissues and under the influence of special agents called ferments, or in artificial media, by imitation realizing natural conditions.[1]

All fermentation represents the combination of: 1, the conditions of development of fermentation; 2, the

[1] Berthelot, *Chimie Organique fondée sur la Synthèse*, p. 571; see, also, Ch. Robin, *Des Fermentations*, Thèse pour l'Agrégation, 1847, p. 5.

agents of fermentation, or ferments, properly so called; 3, fermentable substances.

The conditions of fermentation are: 1st, the presence of water; 2d, the concurrence of a certain temperature from 25° to 40° Cent. on the average; 3d, the intervention of oxygen; 4th, time, that is to say, the sufficiently prolonged contact of the fermentable substances with those other matters which act the part of ferments.

It is evident that the various conditions of fermentation are found in the buccal cavity, united in the highest degree; water, temperature, contact of air, and, as regards time, it may be considerable; for it is in the interstices of the teeth, in the congenital grooves, in the natural fissures or holes which the surface of the teeth so often present, where these phenomena arise localized and sheltered from all disturbance. As for the ferment, whilst the saliva, through the organic albuminoid matter or ptyaline it contains, may itself fill this office, the mouth contains almost constantly, by the fact of alimentation, débris of substances which may play the same rôle, for "every nitrogenous substance, whether of animal or vegetable origin, analogous to albumen and the nitrogenized products of the alteration of these same substances susceptible of undergoing the phenomenon of spontaneous decomposition known as *putrefaction*, may act as a ferment."[1]

The substances most apt to enter into fermentation are ordinarily the proximate essential vegetable and animal principles, which may be ranged under two orders: 1st, proximate azotized principles, albumen, fibrine, caseine, etc.; 2d, the proximate non-azotized principles, the gums,

[1] Berthelot, *Chimie Organique*, etc., p. 575.

the sugars, and their combinations with one another. Thus is seen what a vast field the buccal cavity opens to these acts of fermentation, for alimentation is incessantly supplying it with substances of this nature.

The products of fermentation, that is, the results of the transformation of fermentable substances, may also be arranged into two groups, according as they are or are not azotized.

The azotized substances liable to fermentation in the mouth, by favor of the dental interstices or of the preëxistent interruptions of continuity of tooth substance, bring about the production of the results common in the open air, that is to say, the phenomena of putrefaction with formation of water, of carbonic acid, the breaking up of certain salts, and the setting free of sulphuretted hydrogen and ammoniacal products. The result is most frequently, from our point of view, to give to the mouth the putrid odor it so often has; but the terminal reaction under these circumstances will nevertheless be rather alkaline than acid. Yet if, under the influence of favorable dispositions, the oxidation of these albuminoid substances is carried farther, there may be produced an acid reaction due to the formation of products belonging to the benzoic series, or to the acetic series and its homologues.[1] Among the most constant products of these transformations, we remark the volatile acids (butyric acid, valeric acid, etc.) homologues of acetic acid, and whose mode of action upon the dental tissues will be seen in the relation of our direct experiments.

The non-azotized substances give rise, by their fermentation in the mouth, to various products, among which we shall especially find the peculiar agents of the altera-

[1] Gerhardt, *Traité de Chimie Organique*, vol. iv., pp. 431 and 548.

tion which is dental caries. Of the fermentations which may be ranged in different groups,[1] some have, from our point of view, no importance; such are the fermentations of fatty matters, those of the ethers, of the alcohols, and the dextrinic fermentation of starchy matter. But there are several which touch directly upon and aid in the explanation of our problem; these are the acid fermentations in general, and especially the lactic, butyric, etc., fermentations.

The *lactic fermentation* is produced at the expense of the sugars, of the glucose, of the lactose or sugar of milk, of gums, and of divers other substances allied to sugar. This fermentation is moreover effected with the greatest facility and, in absence of a special ferment, needs but the presence of some azotized matter which at once takes the place of a ferment. This it is which is most frequent in the mouth, and gives to the gingival membrane and to the whitish collections that cover the teeth their acid reaction. Now our direct experiments demonstrate that this agent is very destructive of the dental tissues even in an aqueous solution of 1 part in 100, and we are convinced that, in certain mucous masses which remain long in contact with the teeth, this proportion is often exceeded. M. Pasteur[2] has succeeded in discovering a special lactic ferment. It is the *levûre lactique*, *fermentum lacticum*, in which he recognizes, as well as in the alcoholic, acetic, and other ferments, a living organism, which has led him, in the formation of his theory, to liken the lactic fermentation to a physiologic phenomenon accomplished by a microphyte allied to the ferment of beer. Without entering into the still pend-

[1] Berthelot, *Chimie Organique*, etc., p. 586.

[2] *Compt. Rend. de l'Acad. des Sc.*, vol. xlv., p. 913, and vol. xlvii., p. 224.

ing discussion of this doctrine of fermentation, we will simply say that if the intervention of a living organism in these transformations is admitted to be necessary, the buccal cavity affords, as has been seen, a variety of vegetable and animal parasites, which are, if not identical with, at least very closely allied to those which M. Pasteur has described.

The *butyric fermentation* operates upon many substances, as the sugars, lactic acid, citric acid, tartaric acid, the albuminoids, fibrine. In the sugars it follows the lactic fermentation, so that in the course of a case of caries caused by sugar, as we shall show further on, the fermentation may undergo two successive phases, the lactic and the butyric, both of which exercise their alterant influence on the tissues of the teeth. The butyric fermentation of lactic acid takes place very readily and with great rapidity in the mouth, when, even in the absence of sugars, this agent comes directly in contact with the teeth, as, for example, in the case of vomitings loaded with the gastric fluid, which, as is known, contains free lactic acid. The butyric fermentation of the citric and tartaric acids, when it occurs in the mouth, adds its effects to those of these agents, already so energetic, and if we consider that the albuminoids, fibrine, etc., may by a prolonged stay in suitable conditions produce the same results, we shall easily comprehend the important part taken by butyric acid in the history of dental caries.

The butyric fermentation is effected by means of a microzoön of the family vibrio, the *fermentum butyricum*, discovered by Pasteur in 1861. This vibrio is peculiar, in that the oxygen of the air destroys it,[1] so that it constitutes an organism which lives solely at the expense of

[1] *Comptes Rendus*, vol. liii., p. 1226.

oxygen in combination; it is also especially developed in liquids where it finds albuminoid substances already fermented or oxidized,[1] differing conditions which the cavity of the month perfectly fulfills.

Side by side with these two typical fermentations, the lactic and butyric, which by their frequency and the energy of their action govern a large portion of our subject, we may place other fermentations of the same sort; these are: The succinic, valeric, and propionic fermentation of sugars; the pectic fermentation of fruits; the acetic fermentation of glucose and alcohol, etc.; but these various phenomena are either too little studied as to their mechanism and the special conditions of their formation, or by their final reaction in physiologic conditions able to exert too feeble an influence upon the constitution of the saliva, to be taken into serious consideration. According to the preceding data the buccal cavity, and more particularly the interstices of the teeth, the free borders of the gums, and the divers more favorably situated points of these parts, ought to be regarded as veritable and permanent breeding places of alimentary fermentation. Nevertheless the rapidity and energy of this fermentation vary considerably in different subjects, even in the normal state. In fact we see infinite differences in the nature and in the intensity of these phenomena. Thus, when, in a given case, the saliva is very strongly alkaline, it becomes capable of neutralizing the results of these very fermentations, as fast as they are formed, and this neutralization giving to the surrounding media of the teeth a definite neutral or alkaline reaction, these escape all alteration. If, on the other hand, this alkalinity is feeble, it becomes insufficient to neutralize the

[1] Ch. de Vaureal, *Essai sur les Ferments,* Inaugural Thesis, 1864, p. 101.

effects of the fermentations, and leaves in contact with the teeth a clearly acid reaction which causes the production of caries. It should, nevertheless, be added that, leaving out of view the nature of the primitive reaction of the saliva, the surroundings of the teeth are not necessarily and constantly acid, and we meet with individuals in whom these are perfectly and habitually neutral; we should conclude from this that the buccal fermentations in such cases are wanting or are very feeble, and by practical observation we recognize that this state corresponds to certain conditions of the mouth; the saliva is fluid, without being viscous, the surfaces of the teeth and gums are free from mucus, and there is a notable production of tartar. The truth is that the mucus and the viscous quality of the saliva are two circumstances very favorable to fermentation, the first serving as the medium, the second favoring the development of these phenomena by means of the ptyaline to which this viscous quality is due, and which is at the same time susceptible of taking on the action of a ferment.

These considerations have for us so precise a significance that, whenever there is found in the mouth limpidity of the saliva and absence of the whitish mucous deposits in contact with the teeth, it may be concluded *a priori* that the reaction of the surroundings of the teeth is neutral, and that the teeth are ordinarily free from caries; if, on the contrary, the saliva is viscous and ropy within the dental arches, as is sometimes observed in an extreme degree, we find abundant mucous collections at the surface of the teeth, and the teeth are themselves carious.

These extreme conditions of absolute integrity or grave alteration of the teeth have their explanation in the more or less fermentable qualities of the saliva, and

the circumstances favoring these acts of fermentation. If we regard in one general view the various states of the saliva in man, we may determine three well-marked classes; *the first* composed of *neutral salivas*, without sensible predominance of the results of buccal fermentations over the alkaline condition of the saliva, and this is where we should theoretically place the point of absolute integrity of the teeth and gums. *The second*, composed of salivas *alkaline* through predominance of salivary phosphates and carbonates above the products of fermentation, or through the entire absence of all phenomena of fermentation. The teeth under such conditions remain absolutely protected from all alteration, and the inconvenience which may result from this state is simply the deposit of masses of tartar with their ordinary effects on the gums. Finally *the third*, comprising the salivas with an *acid* reaction, resulting at times from the incapability of their alkaline elements to neutralize the fermentations, at others from the intense activity of the latter. This case is the gravest, for if it is prolonged for a period of sufficient length, or if it is habitual and permanent, it carries with it the progressive and complete destruction of the teeth. These three states of the saliva, which may be called fundamental, and which are constantly to be observed in individuals in a state of health, should therefore be regarded as normal and resulting, in the absence of every morbid circumstance, from primordial conditions of the mouth, or of the buccal fluids. They may, moreover, be reproduced in the different members of the same family and become transmissible by heredity in the same way as every other congenital predisposition. Thus it is that these considerations, limited at first to certain subjects, may be elevated to the

still more general questions of family or of race, and contribute to the explanation of those kinds of caries which become with certain races and in certain countries an affection which may be called endemic.

(*b.*) Direct Introduction into the Saliva of Substances able to attack the Teeth. The substances injurious to the teeth which may find their way accidentally into the saliva, may come either from the food or from the use of certain medicines. Alimentation brings into the mouth a long series of agents destructive to the teeth: these are the organic acids, acetic, citric, malic, lactic, etc.; the acid salts, the oxalates and the tartrates, whose action upon the teeth is easily foreseen and which our experiments will clearly demonstrate. Moreover the peculiar sensation called *setting on edge*, which is produced after eating an acid fruit, is well known. This sensation corresponds to a direct alteration of the superficies of the tooth by the acid agent of the fruit. Its immediate result is to render the surfaces of the teeth rough to the tongue, as if deprived of their polish, and if by an accidental cause, wear, for example, the enamel layer is wanting at a point of the crown, the acid agent, finding a less resisting soil and one nearer the sensible centre of the organ, may give rise to veritable pain. We ought to add that in the latter case the sensation is immediate, — a fact which would exclude the possibility of a chemical change that always demands a certain time for its action. We must therefore explain this effect by capillary transportation through the dentinal canalicules of the substances in question and of the irritation thus caused by them to the pulp itself.

The action of the organic acids cannot then be contested, and will moreover be developed in the following

paragraph. It should consequently be hereafter considered as a direct cause of caries, when, by the habitual use of certain vegetable food, or the abuse of certain fruits, the teeth become in an almost permanent manner exposed to their influence. Thus may be explained the habitual caries of certain peoples accustomed to some special mode of alimentation, and also that shown by certain species of animals, the apes, for instance, and above all by the large species, chimpanzees and gorillas, which are essentially frugivorous.[1] The medicaments employed in the treatment of local affections of the mouth and pharynx, acting injuriously upon the dental organ, are primarily the mineral acids, chlorhydric, nitric, the acid nitrate of mercury, etc., agents whose disastrous effect upon the ivory and enamel we have no need to explain, and which render it necessary to prescribe for the health of the mouth whenever they have been in contact with the teeth. We observe in fact that among those patients who have on several occasions undergone applications of this nature, the teeth present general phenomena of sensibility or of pain, at times excessive, which result from the alterations of greater or less depth experienced in their tissue. These alterations, it is true, when they are limited to a small extent of surface, are often arrested, and may even, upon abandoning the use of the agents, remain definitively stationary; but it will be understood that, even after this time of arrest, the lesion of the tooth, whatever its depth, is none the less irreparable, and constitutes in the sequel a new cause predisposing to caries.

Next to the use of energetic mineral acids we will name alum, so often used in the treatment of certain affections of the mouth and of the pharynx, and whose

[1] See Du Chaillu, *loc. cit.*

destructive action directed specially and exclusively upon the enamel of the teeth our experiments will establish, a circumstance which gives to its employment a character of peculiar gravity. We have many times observed patients who had been treated for some time by means of this medicament, in whom the enamel presented superficial alterations, generalized, so to speak, on all the teeth. Mastication, the slightest changes of temperature, the contact of foreign bodies, had become intolerable.

We include under the title of medicament the alum employed in certain dentifrices which owe to this substance the property of giving to enamel a dazzling brilliancy resulting from the alteration they cause in it. A great number of tooth-powders in the market owe their success to a notable proportion of alum in their composition. The influence of these dentifrices becomes by prolonged use especially deleterious for the enamel, which little by little becomes chalky and friable, is detached by fragments, and ends by exposing the underlying dentine.

The use of other acid medicines, the perchloride of iron, when it is not absolutely neutral, the nitrate of silver, etc., may call for the same remarks. The latter agent, used in applications upon the gums in the neighborhood of the teeth, has moreover the inconvenience of discoloring them with black stains which are almost indelible.

2. *Morbid Modifications of the Saliva.* — By morbid modifications of the saliva we understand the changes which the influence of pathologic conditions brings into its secretion or into its composition. They may be classified under three principal heads.

*a*. Local affections of the mouth and of the pharynx.

*b*. General acute diseases.

*c*. General chronic affections.

The local conditions of the mouth and the neighboring parts which may disturb the salivary reactions are inflammatory affections of the mucous membrane and local complications of maladies of another order.

It is a fact of clinical observation that stomatitis, amygdalitis, and pharyngitis exercise during their existence an incontestable influence upon the stains or deposits that cover the teeth. These stains ordinarily become dissolved, as also do the deposits if they are calcareous, as tartar. On the other hand, the mucous collections increase at the necks of the teeth, and are the seats of sensations of irritation which often cause patients to say that their teeth seem to have been rubbed with sorrel or lemon. This sensation is very correct, and corresponds in fact precisely to the phenomenon which has taken place. Under the influence of the inflammatory affection of the mucous membrane, there takes place a hypersecretion of mucus, a marked elevation of the temperature of the mouth, and at the same time some difficulty for the patients to give to their teeth their habitual care, all conditions which give to the salivary fermentations a greater intensity and rapidity; then the acid products, lactic or others, form at the surfaces of the teeth where they occasion their habitual disturbances. If the inflammation has been slight or of short duration, the effects are limited to a slight superficial alteration of the crown; but if the malady has lasted long, or has been of considerable severity, the locally produced accidents of the teeth take on a greater intensity, and occasion in the dental interstices or in other favorable positions the appearance of true caries.

These considerations belong to inflammatory affections not only of the mouth, as all the forms of stomatitis, but also to the various kinds of angina whose effects reflect upon the state of the buccal cavity nearly as energetically as stomatitis itself. We would especially call attention to *angina tonsillaris*, so frequent in infants, in whom it may exist for a long time in a chronic condition with intervals of acute periods, circumstances capable of explaining the reason of the caries which so often ravages the temporary teeth, and also the permanent ones shortly after their eruption. The different chronic forms of buccal or pharyngeal affections have the same influence. We will now specially mention the follicular pharyngitis which is almost constantly accompanied by numerous cases of caries whose gravity is frequently augmented by the various medicines employed, as we have hereinbefore seen.

The *general acute affections* favor the production of dental caries in the following manner: Under the influence of pathologic conditions of this kind, pyrexiæ, eruptive fevers, inflammatory diseases, phlegmasiæ of glandular textures, marsh fevers, etc., there are produced by reflex action upon the mouth, immediate phenomena which are the suppression, more or less complete, of the salivary liquids, properly so called, whence arise the dryness of the tongue and the habitual thirst of the sick, and simultaneously a hypersecretion of mucus, whence the foulness of the tongue and the mucous deposits at the surfaces of the teeth and the gums. To these two circumstances are added the inaction of the buccal cavity, the suppression of the masticatory movements, by abstinence from food, and the mouth is thus placed under entirely new conditions. The buccal mucus produced incessantly and in

abundance, becoming deposited in position, passes rapidly to the concrete state and forms those hard and variously colored masses called *fuliginosities.* These mucous deposits, which the saliva dried up in its source can neither remove nor dissolve, remain thus in contact with the teeth during the whole period of the disease, which is often of long duration; now, with these masses of mucus are necessarily mingled various albuminoid or starchy particles from the food, most frequently of sugar and gums from the diet-drinks, and there becomes established in contact with the teeth a hot-bed of fermentation of the most active kind. If the disease is of an intestinal nature, acute enteritis, typhoid fever, etc., these same effects in the mouth are much exalted, and the ulterior disturbances more considerable. Indeed, when, during convalescence from an affection of this kind, and more especially from typhoid fever, we undertake to remove the mucous crusts which encumber the mouth, we find that the teeth have undergone a local alteration, particularly marked at their necks, appearing generally as minute yellowish sunken spots, with loss of the enamel and exposure of the dentine, which forms the bottom of the depression and becomes the seat of a very acute sensibility on contact with an instrument, or to the impression of a liquid of too low or too elevated a temperature. These local consequences of acute affections upon the mouth may be verified every day; and if by means of slightly moistened litmus paper we test the reaction of the mucous crusts themselves or of the surface of the teeth, we find them constantly and clearly acid. Very few patients attacked by acute affections escape these consequences, above all, if, by a quite common negligence, no attention has been given to the care of the mouth, nor any means taken to

neutralize the effects of the local fermentation. Nevertheless we find some individuals whose teeth are of so perfect and robust a constitution and structure, that they are found upon convalescence in their primitive condition. Such examples are rare; but we can see with what simple means these disorders of which we have spoken may be evaded, the daily removal of the collections, and the repeated application of an alkaline wash to the mouth during the whole period of the disease, completely neutralizing its influence.

These chemical changes of the saliva during sickness producing a definite acid reaction upon litmus paper, are not facts of recent observation. In 1835, Donné [1] had shown that the majority of acute diseases bring with them this uniform result in the mouth, with simple variations in the intensity of the reaction. Thus in pneumonia, bronchitis, acute pleurisy, he had remarked the more or less acid condition of the mouth. In certain intestinal affections, gastritis, enteritis, typhoid fevers of various forms, his clinical observations, collected with great care, have established that the saliva, primitively alkaline at the beginning of the malady, becomes successively neutral, afterwards acid, taking on again at convalescence its primitive reaction. These signs had even acquired in the mind of Donné an importance sufficient to become in his hands an element of determining the gravity and the critical periods of the maladies, as well as a means of differential diagnosis.

The *chronic affections* and certain diatheses have a not less incontestable influence upon the production of dental

[1] See *Recherches sur les Caractères Chimiques de la Salive, considérés comme Moyen de Diagnostic dans quelques Affections de l'Estomac, Archives Génér. de Médecine,* 1835. *Histoire Physiologique et Pathologique de la Salive,* 1836.

caries. They always act, however, in a somewhat different manner: the secretion of the salivas proper is not sensibly modified as to quantity; but the state of the buccal liquids offers certain peculiarities appreciable even by direct examination. The saliva becomes more viscous, forming numerous filaments between the teeth on the separation of the jaws ; the patients themselves often notice this as it renders difficult the expulsion of the spittle, and gives to the mouth a peculiar sensation of soapiness or greasiness. Moreover the teeth do not show the deposit of tartar, except sometimes at the posterior face of the lower incisors, near the ducts of the submaxillary and sublingual glands. They are generally covered with greenish spots which we have shown to come from the food, and which have often seemed to us to coincide with the acid secretions of the mouth. These stains, which frequently cover the teeth with the exception of the masticating surfaces, are at the same time thicker and larger, especially in the vicinity of the necks and in the interstices of the teeth, where they always accompany the very abundant whitish mucous deposits which become the seats of buccal fermentations. These deposits nevertheless are not concrete and hard as during an acute affection, but remain soft, cheesy, and very easy to detach from the surface of the teeth, and present, with a clearly acid reaction, the constitution we have hereinbefore remarked.

The chronic affections which produce these effects are principally the intestinal forms, enteritis, dysentery, gastralgia, dyspepsia. Their effect is to exaggerate the proportion of ptyaline, the agent of viscidity and of fermentation, and to excite a hypersecretion of mucus, two phenomena caused either by the direct influence of intes-

tinal alteration, or by reflex action of the general condition upon the conditions of the mouth. These circumstances are easily observed in the course of the diseases mentioned, when we perceive that the teeth, subjected to the acid effects of their media, are quickly attacked by caries of a rapid progress, affecting at one and the same time a considerable number or even the whole of them. If afterwards there occurs a suspension in the progress of the disease or a complete cure, the caries in the way of development spontaneously ceases, passes to the state of dry caries and so remains as long as the state of health continues, to take up again its usual course if the malady ever reappears.

Thus is established the relation so often observed, but which up to this day has not been explained, between chronic diseases and dental caries. Certain physiological conditions, pregnancy, for example, influence the teeth in the same way. There has been in fact always recognized in this condition an action upon the formation of caries, without any relation, either direct or reflex, having been established between the uterus and the conditions of the mouth. Pregnancy, in our opinion, causes the production of caries in two ways; first, disturbances of the digestive functions, vomitings, etc., modifying the reaction of the buccal liquids ; and secondly, by means of the compression which the distended uterus exercises about the middle and towards the end of the gestation upon the stomach and intestines, producing the same results in the mouth.

As for nursing, to which effects of the same kind upon the teeth have been attributed, we have not been able to demonstrate any, and we are led to believe that this pretended influence may be due rather to the pregnancy

itself, or may result from complication with other affections. The diatheses on which ancient authors so freely placed the responsibility of all morbid phenomena whose explanation was difficult, have likewise been full often evoked in the etiology of dental caries; the rheumatic, gouty, syphilitic, and other diatheses are in this category. We cannot recognize in these general conditions any manifest influence, except when they occur in infancy by interrupting the phenomena of evolution of the dental tissues and giving occasion to the defects of structure and of composition before examined. But at adult age they cannot alter the teeth otherwise than by the morbid complications they may occasion which act in the manner proper to each.

### § 3. *Direct Experiments: Experimental Production of Artificial Caries.*

The preceding considerations tend to establish that dental caries results from a purely chemical alteration of the enamel and ivory of the teeth either by the products of acid fermentation developed in the saliva, or by active agents introduced directly into the mouth. Now, if this theory is correct, we should be able to obtain the same effects by subjecting sound human teeth out of the body and deprived of life to the direct action of the same agents which produce this affection in the economy. This is in fact possible, and we shall relate and develop a series of experiments by which, sometimes in the mouth and under the ordinary conditions of development of natural caries, sometimes in liquids artificially prepared, we have produced changes identical with that of this malady.

Thus will be demonstrated, as it seems, without doubt, the true nature of dental caries, which it will be impossi-

ble to regard henceforward as an affection of internal and organic origin, or a vital lesion of nutrition, as has been generally believed up to this time.

Two methods were at hand for the solution of this problem: the first consisted in producing caries by means of human saliva; the second, to excite it in artificial liquids, imitating the composition of saliva, or at least containing in solution the special agent which exercises upon the tooth its ordinary action. We have therefore divided our experiments into two groups: A. Experiments in the natural saliva and on the living body. B. Laboratory experiments.

A. Experiments in the Saliva. The experiments upon teeth plunged in human saliva cannot be carried on in the liquid taken from the mouth, on account of its rapid alteration, but in the cavity of the mouth itself, where certain facts of special practice come in play to serve as veritable experiments. It is well known that in certain cases of prosthetic appliances there have been used apparatus carved from a mass of elephant or hippopotamus tusk, or else pieces composed of a metallic or other base mounted with human teeth. These appliances, nowadays little employed, had given occasion to singular observations. In the mouths of certain individuals they wore for a considerable period and remained without any alteration; whilst in the mouths of others they underwent softening and a more or less rapid destruction, which sometimes took place so energetically that an apparatus of this kind was attacked and destroyed at the end of a few months. These alterations resembled those presented by ivory submitted to the action of weak acids, and it had been thence concluded that in the first case the vicinity of the gums was alkaline and in the latter acid.

If the appliance was formed of ivory cut from one homogeneous mass, and deprived at all points of its protection of enamel, the alteration produced ought to be uniform and general, as ordinarily happens. Nevertheless in certain more favorable circumstances, as on the parts in contact with remaining teeth, or applied against the mucous membrane in the neighborhood of the remains of the root of a tooth, the destruction of the ivory becomes localized and limited, and a veritable cavity is formed, softened at the bottom, variously colored in brown or black, and filled with detritus with an acid reaction. Now the places of election of this artificial alteration are precisely those most favorable to the development of the phenomena of fermentation and which predispose in a special manner to the formation of natural caries. If the appliance is composed of human teeth the alteration takes on in a still greater degree the appearances of caries, and in certain cases represents it with exactness.

Some examples will make these considerations more prominent.

Obs. I. Madame M., thirty years, in very delicate health, affected with the dyspepsia ordinarily accompanying hypochondria, at the age of twenty lost a number of teeth of the upper jaw, attacked and destroyed by rapid caries. The roots of these teeth remain indolent in the alveoli, but their enlarged canals are the habitual receptacles of mucus and débris of food, while at the same time the neighboring gum is generally red, puffy, and fungous. The remaining teeth and the free borders of the gums are at various points of the mouth absolutely devoid of tartar, but covered with abundant masses of a whitish hardened mucus whose reaction is clearly acid. The greater part of these teeth have been plugged, on account of previous caries. Several ap-

pliances carved from hippopotamus ivory have been successively tried, none of which have lasted in the mouth more than from eight to ten months on the average. The last one was worn only eight months. It is composed of three incisors, two right bicuspids, and one, the second, left bicuspid. It was held in place by rings around the first molars, carved in the mass and kept from friction by two small pegs of wood left slightly projecting from the body of the piece.

This apparatus during its eight months' stay in the mouth has undergone the following changes. The whole mass is translucent and amber-colored; taken between the fingers it is flexible and spongy; the two points supporting the wooden pegs have become so softened as to have lost them and formed in their place a huge blackened cavity, with softened and gelatinized walls; the three points of the concave surface of the appliance corresponding to the remaining roots of the incisors show a similar change, which in one place has caused the complete perforation of the piece. All other parts of the mass are softened in an equal degree. The detritus collected at the bottom of the points of alteration and placed in a little distilled water had an acid reaction, and the whole apparatus a faint, sickening odor.

We believe that these alterations of the ivory of the appliance, situated principally at the points where the action of fermentation is most likely to be induced, the hollows of the remaining roots, the places where the wooden pegs were set, etc., should be regarded as true caries.

The following examples add further proof: —

Obs. II. Miss F., thirty-five, has been troubled for seven years with an obstinate gastralgia. During this period a great number of carious cavities have been formed which have necessitated time after time appropriate treatment; there is no appearance of tartar in any part of the mouth, and the teeth are habitually covered with abundant whitish masses of hardened mucus; the saliva is highly viscous and thready. The right

lateral upper incisor was one of the first attacked by caries, which caused the loss of the whole crown. This was replaced five years ago by a natural tooth mounted on a metallic pivot in the canal of the remaining root. This tooth after this lapse of time was found in the following condition. The cut surface in contact with the root and around the pivot shows a uniform softening of a brown shade; the pivot is loose through the enlargement of the canal in which it was fixed: the two proximal sides of the tooth each shows a vast cavity of a light yellowish color, and having every character of ordinary caries. (Fig. 10, A.)

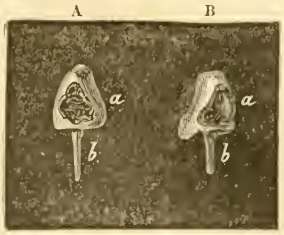



FIG. 10. Artificial Caries developed in two human teeth, worn as pivot teeth; *aa*. teeth with their caries; *bb*. pivots

The enamel examined with an excavator shows a free excavation slightly irregular, and directed transversely towards that of the opposite side. One of these cavities, deeper than the other, has even exposed and isolated the metallic pivot.

OBS. III. Mr. B., forty, of a very feeble and cachectic constitution on account of marsh fever contracted ten years ago in Spain, has been during this whole period in a dyspeptic condition with chronic enteritis, frequent diarrhœas, and various other general symptoms: the saliva is viscous, the mouth habitually pasty, especially in the morning, and loaded with abundant flocky mucus; the teeth, otherwise excellent, have suffered greatly during this period, and are generally affected with rapidly progressing caries, and painful. One of them, the superior central incisor, was replaced eight years ago by a human tooth on a metallic pivot. This tooth, to-day, after a stay of eight years in the mouth, shows a vast cavity on its outer side. This cavity, a little irregular and of an egg-shape, occupies the entire width of this side and the greater part of its height. The excavation not so soft at the bottom as in the preceding case, and of an intense black. (Fig. 10, B.)

Obs. IV. Mr. G., thirty-seven, has been for four years afflicted with granular pharyngo-laryngitis, very obstinate, with exacerbations, returning every two or three months, and bringing with it a veritable acute stomatitis with abundant salivation, and considerable mucous deposits on the surfaces of the teeth. The teeth, up to this time perfectly sound, have become affected, and it may be said that to-day they are almost all carious, the caries appearing to affect by preference the necks of the teeth in contact with the free border of the gums. The lower front teeth themselves, ordinarily spared, have been attacked, and one of them having entirely lost its crown, it was replaced two years ago by a human tooth on a small gold plate. To-day this tooth is affected in the same degree and in the same manner as its neighbors, and shows, not one or two sharply defined cavities as in the previous observations, but two deep grooves occupying the whole length of the lateral surfaces of the tooth, and united below to a large softened surface corresponding to the plate and to the tenon uniting it. This alteration shows the dark color presented by every case of caries in this mouth.

*Conclusions from the Preceding Observations.* It results from the examples just given, that ivory in general, and particularly the human teeth employed in artificial appliances, undergoes an alteration which presents all the external characteristics of natural caries, when used in the mouths of individuals presenting otherwise the ordinary conditions of development of this malady, and we may directly oppose to these examples the cases where apparatus composed of the same materials applied to supply the loss or fracture of a tooth have been kept indefinitely in mouths otherwise unsuited to the development of caries. The artificial cavities so produced have the same conditions of form and direction as pathologic caries; the position is the same, and in the two pieces corresponds to the points of the surface of the teeth

most favorable to chemical action. We find also in factitious caries the same differences of coloring as in the other, proving incontestably, as we have already shown, that these differences are due to secondary peculiarities of a chemical nature, with isolation of certain coloring matters, and in intimate relation with the rapid or slow progress of the alteration. A fundamental distinction must nevertheless be observed; it consists in the absence of all phenomena of reaction on the part of the tooth and of the absent dental pulp, whilst in pathologic caries the injured organ reacts and struggles against the invasion of the disease in the manner we have shown in a previous work. Except this sole difference of a vital character the two alterations are identical in nature and in appearance; so that, all other conditions being equal, caries will attack and destroy more rapidly a dead tooth, inert and passive, than a living one, which most frequently and in a certain measure opposes to the malady a resistance variable in its energy, but at times sufficient to completely arrest its progress.

B. Laboratory Experiments. — *General Conditions of the Experiments.* The experiments we are about to describe and whose results we are to examine having for their end to ascertain the influence upon the dental tissues of certain substances which may be found in the mouth, we have endeavored, so far as was possible, to imitate the ordinary conditions of this cavity. The agents experimented with should necessarily be soluble in water and consequently in saliva: the degree of concentration should vary in order to establish approximately the point where the change takes place, without reaching a condition which would never be met with physiologically.

Therefore we have generally, and except under peculiar circumstances, made and used two solutions simultaneously, the first in the proportion of one in a thousand, one gram of the substance to one liter of water; the second in the proportion of one in a hundred, or one gram of the substance to one hundred grams of water. Generally hydrant water has been used, save in the cases where we have wished to study in a vacuum and without possible modification the action of any substance alterable in contact with this liquid; at such times we have employed distilled water. The solutions enclosed in flasks loosely corked, have been thus left at the ordinary temperature during a uniform period of *two years*, and the external characteristics as well as the reactions have been noted at the beginning and end of each experiment.

The majority of the solutions experimented with being left exposed to the air should undergo various alterations, special fermentations or putrefactions, properly so called. And we should also study the changes which take place within these liquids and determine their effects. In some cases the addition of a few drops of creosote to the liquid has resulted in retarding, and in others in completely checking the alterations, thus sensibly changing the results. We shall keep a record of these variations. Finally, undertaking certain experiments in a vacuum, we brought the liquids to the boiling point and placed them in flasks drawn out and hermetically sealed in the flame.

The substances chosen for experiment should answer several special indications; first, they should be such as may be found in the buccal cavity and in contact with the teeth in sufficient quantity to exercise upon them a marked action; second, they should remain there long

enough to exert their influence, which the union of certain local conditions makes possible in the mouth. As to the substances themselves, we have chosen them among those whose reaction was primitively acid, or could become so by means of fermentation. We shall proceed to examine the facts relative to each of these in the following order: —

The sugars.
Lactic acid.
Butyric acid.
Citric acid.
Malic acid.
Cider.
Carbonic acid.
Albumen and albuminoids.
Alum.
Oxalic acid and the acid oxalates.
Acetic acid.
Tartaric acid, and the acid tartrates.
Chloride of sodium.
Tannin.

We have omitted, as will be seen, on the one hand the strong acids, nitric, sulphuric, etc., whose action upon the teeth is well understood, and which, moreover, are not habitually found in the mouth; on the other, those neutral substances of a fixed reaction from which no appreciable action can be looked for.

The objects used for the experiments were composed of two groups of human teeth, adult, and perfectly sound, except a few taken intentionally showing a beginning more or less advanced of caries. In the first group the teeth were absolutely free in the liquids; in the second they were completely surrounded with a coating of sealing-wax

applied carefully as a continuous envelope and pierced at only one point with a circular opening of about one to two millimeters in diameter, exposing the enamel or the ivory in such a manner as to localize the action of the liquid. This process represents an imitation of the conditions of development of caries in the mouth where it most frequently attacks only limited portions of the surface of the organ, the most favorably disposed either from their conformation or their situation. Finally, to these two groups of teeth we have added, in a few experiments, fragments of adult human bone, in order to test comparatively the influence of some agents upon the bones and upon the teeth, an influence otherwise uniform as regards the dentine and the osseous tissue, whose chemical composition presents many analogies.

(*a.*) Sugars.

Experiment I. — A solution in water of cane sugar in the proportion of one to three (three hundred grams in a liter of water) gives at the end of two years the following results: The liquid is reddish, covered with a thick layer of mould; reaction clearly acid, a faint odor; taken between the fingers the liquid still has its thick and syrupy character.

Fig. 11. Human molar which has been left for two years in a solution of sugar.

The teeth placed in the solution are completely softened and black, the roots having a gelatinous consistency; the enamel is friable as chalk, detached at several points and showing the ivory beneath it to have undergone the same degree of alteration as the roots (Fig. 11). The teeth, protected by a coating of sealing-wax, show at the exposed point an alteration identical with the preceding, and which, thus localized, has produced a cavity having all the characteristics of caries. The edges of the enamel are soft and friable and the bottom soft and black (Fig. 12).

A fragment of bone, a spinous process of a vertebra, is entirely softened and blackened.

Fig. 12. Artificial caries from sugar, developed on an exposed point of the anterior face of the crown of an adult superior incisor.

Exp. II. — To a solution identical with the preceding has been added a fragment of animal matter, with the purpose of making the fermentation more active, and the whole exposed to the air in a bottle loosely corked, during the same period. The liquid is clearly acid and covered with thick mould. The alteration of the teeth freely exposed in this solution has been carried to the last degree, and presents, with a general softening of the whole substance, so considerable a reduction of volume as to render them unrecognizable The protected teeth have likewise undergone an alteration so profound, that, through the exposed point and in spite of the protecting coating which covered the rest of the surface, they are softened through their whole extent, and uniformly penetrated with the dark coloration common to this kind of action. Moreover, this very exposed point of enamel is itself considerably excavated.

Exp. III. — To the same solution have been added a few drops of creosote with the intention, this time, of retarding the phenomena of alteration. The color and the transparency of the liquid have not, after two years, markedly changed; it is only slightly cloudy; its reaction is clearly acid; there is a thin layer of mould upon its surface; the odor is faint and slightly fetid, on account of the creosote.

Two teeth freely exposed in it show an advanced alteration, roots which are softened and brown, without the intense black color of the preceding experiments. The enamel is chalky and friable, except at some points where it has kept its ordinary polish. The crown of one of them, a lower molar, shows an excavation, true caries, which has arisen in a primitive intertubercular fissure of the triturating face. Three teeth, pro-

tected by wax, with the exception of a point over the enamel, have undergone an alteration which, after having destroyed the whole of the uncovered enamel, has penetrated the ivory to but a slight depth, forming cavities which have all the characteristics of caries (Fig. 13). Nevertheless, in this experiment we remark an exception in the case of an adult canine of an apparently irreproachable conformation, which, having the middle point of the anterior surface of the crown exposed, has escaped the action of the liquid without experiencing the least alteration. A fragment of bone, a transverse process of a vertebra, shows less alteration than in the preceding experiments.

FIG. 13. Artificial caries from sugar developed in the posterior face of an adult upper canine upon a point *a* denuded.

EXP. IV. — A one third solution of glucose was placed in the same conditions with the addition of a few drops of creosote. The liquid, after two years, has not at all changed in its appearance; there is no mould upon its surface, its transparency is perfect, its odor faint, its acid reaction very feeble. These facts show clearly that the liquid has not fermented.

On the freely exposed teeth and on the uncovered points of the protected teeth, there can be seen no alteration; neither can there on the fragment of bone placed in the liquid.

EXP. V. — A cold saturated aqueous solution of sugar of milk, placed in the same conditions as the preceding, has given the following results: The liquid remains clear; there is no mouldiness or deposit whatever; its reaction is perfectly neutral, and the teeth, whether free or protected, have undergone no alteration.

EXP. VI. — A one third solution in distilled water of cane sugar, filtered and raised to boiling heat, was placed in a flask whose neck had been drawn down and hermetically sealed in the flame, and left to itself for two years. A group of sound human teeth, weighed with the greatest care, had been pre-

viously introduced into the boiling liquid. After removal they were found in a state of perfect integrity, and when weighed after being washed and dried, proved to have undergone no loss nor any appreciable alteration.

Exp. VII.—A solution of glucose under identical conditions gave the same negative results.

*Conclusions from the Experiments relating to the Sugars.* — It follows from the preceding experiments that sugar does not exert directly, that is, in its quality as sugar, any destructive action upon the teeth. Experiments made *in vacuo* furnish irrefutable proof of this. Those solutions which whether spontaneously or by the addition of substances retarding fermentation, have experienced partial modifications, have produced but slight and inextensive alterations; and finally the sugary solutions left to themselves or with substances added which can take the place of ferments have produced most disastrous results upon teeth subjected to their influence.

Now, the fermentation of sugars is of two orders: Under the influence of the leaven of beer it is alcoholic, and with this we have nothing to do; under the influence of nitrogenous ferments (albuminoid substances, etc.), the fermentation may take two directions; it is lactic or butyric; and most frequently passes successively from one to the other. The phenomenon of the production of lactic acid is effected in a very simple way, and by a division of the sugar, $C_6\ H_{12}\ O_6$, into two equivalents of lactic acid, $2\ (C_3\ H_6\ O_3)$. As for the butyric formation, it takes place with the giving off of hydrogen and the production of carbonic and butyric acids.

$$\underbrace{C_6\ H_{12}\ O_6}_{\text{Sugar.}} = \underbrace{C_4\ H_8\ O_2}_{\text{Butyric Acid.}} + \underbrace{2\ C\ O_2}_{\text{Carbonic Acid, 2 equivalents.}} + \underbrace{2\ H{-}H}_{\text{Hydrogen.}}$$

These two phenomena, which occur in open air and at ordinary temperature, find in the mouth conditions eminently favorable to their energetic and rapid production.

In every case these acts of fermentation of the sugars are preceded, as regards cane and beet sugars, by their passage to the state of glucose and levulose, express condition of their fermentation. This passage is produced by the fixation of a double equivalent of water.

$$\underbrace{C_{12}\,H_{22}\,O_{11}}_{\text{1 equivalent of cane sugar.}} + \underbrace{2\,H_2\,O}_{\text{Water, 2 equivalents.}} = \underbrace{C_6\,H_{12}\,O_6.\,H_2\,O}_{\text{Glucose.}} + \underbrace{C_6\,H_{12}\,O_6}_{\text{Levulose.}}$$

The sugars therefore exercise an altering action upon the dental tissues only on condition of undergoing modifications of the nature of fermentation and leading to the formation of lactic acid, afterwards successively butyric acid and some of its derivatives, propionic, valeric, etc., acids, agents which, as we shall see, have a most energetic action, directly destructive, upon the teeth.

Thus by our experiments, the question of caries produced by sugar, which daily observation had long admitted without demonstration, has been resolved. In fact it had been agreed that the use of this substance in its different forms, cakes, honey, etc., seemed to produce caries of the teeth. Persons engaged in certain occupations, as confectioners and cooks, experienced the same effects; moreover it is acknowledged that the contact of the saliva impregnated with sugary substances produces upon some teeth, deprived of their enamel by wear or commencing caries, the sensation called "setting on edge," and even real pain, just in the same way as do acids. All these facts find here their explanation.

The experiments, whose results we have just set forth, were instituted by us several years ago and have already

been put on record.[1] Latterly, an experimenter, M. Mantegazza, professor of general pathology at the University of Pavia,[2] desiring to elucidate this question of the action of sugar upon the teeth, has undertaken a series of observations which have led him to nearly the same conclusions as ours. Nevertheless his processes were different. Human teeth dried and weighed were introduced into solutions of sugar of varying degrees of concentration, one portion in distilled water, another in saliva taken directly from the mouth. The liquids at first neutral or alkaline, had at the end of some days an acid reaction; the liquid contained traces of lime, and the teeth had lost in weight. Therefore it was certain that the sugar had attacked the teeth. It remained then to determine experimentally if this change had taken place from the sugar directly or by the transformations it undergoes when exposed to the air. This was omitted in the observations of M. Mantegazza. Our own personal experiments have, it seems to us, refuted in advance every objection or doubt which this kind of question may raise.

(*b.*) Lactic Acid.

Exp. I.—A solution of one part in one thousand, or 1 gram of lactic acid to 1 liter of water, originally having an extremely feeble acid reaction, have not at the end of two years perceptibly changed, if we except a mass of mildew at the bottom of the glass, reaction neutral to litmus test paper. The teeth, whether free or protected by a layer of wax, appear to have undergone no appreciable change.

Exp. II.—A solution identical with the preceding with some drops of creosote gave the same negative results.

[1] See *Dict.* cited, 12th edition, art. *Carie Dentaire.*

[2] *De l'Action du Sucre et de quelques Substances Acids sur les Dents,* Pavia, 1865.

Exp. III. — A solution of lactic acid in the proportion of one part in one hundred, water two hundred grams, lactic acid two grams, gives the following results: The liquid is limpid and transparent, covered with a thick layer of mould; its reaction is neutral to litmus paper; it has an odor somewhat faint and fetid. The teeth left exposed in the liquid have undergone a profound and uniform alteration; the roots are softened, flexible, and, as it were, gelatinous, and considerably reduced in volume, principally in the direction of their length; the enamel is chalky, friable, detached from its connection at the surface of the crown, and crumbling to a white powder at the least scratch. The whole mass of the teeth presents a general brown coloration. The protected teeth, with a point left exposed, have undergone a change of the same character. A point upon the surface of a molar is the seat of a veritable caries that has penetrated about three or four millimeters into its substance. Another free edge of an upper incisor of an aged person, deprived of enamel by wear, shows caries in the form of a gutter (Fig. 14, A). A third point, the anterior face of the crown of an adult incisor, has experienced but a relatively slight change, consisting of a dissociation of the elements of the enamel, reaching hardly to the superficial layer of the ivory. A fragment of bone, added to the foregoing preparations, has undergone complete softening, almost as much so as in the experiments with sugar.

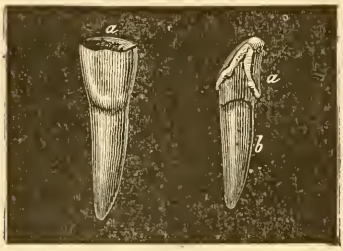



Fig. 14. Artificial Caries from Lactic Acid. A. Caries developed at the exposed end of a superior adult incisor. B. General alteration of an incisor plunged without protection in the solution: *a*. enamel crushed and friable; *b*. root softened to considerable depth and brown.

*Conclusions from the Experiments with Lactic Acid.* — Lactic acid in the proportion of one in one thousand exerts upon the teeth only a moderate action, apprecia-

ble by the passage of the solution, at first feebly acid, to the neutral reaction; but at a higher degree of concentration, the one in one hundred, it acts energetically and uniformly upon the dental tissues, producing changes which strongly resemble those from the sugars, and have all the characteristics of veritable caries.

Lactic acid is, as is known, an energetic solvent of the phosphates and carbonates, and its relative fixity indicates sufficiently that it can act in such cases by itself and without undergoing any modification or fermentation.

This agent should be considered as one of the most frequent alterants which occur in the mouth; besides that it forms, as we see, spontaneously, it is carried there in other ways, for example, in matters vomited or eructed, in sea-sickness, the diseases, etc., and it is known that the gastric juice contains in a free state a very notable proportion of this acid.

### (*c.*) Butyric Acid.

Exp. I. — Solution of one part in one thousand: butyric acid one gram, water one liter. The liquid, originally acid, at the end of two years has preserved its limpidity, its transparency, its reaction, and all its characteristics. It has no covering of mould.

The exposed teeth present a general alteration through their whole substance; the enamel, white, opaque, and chalky, is brittle to an excavator, which removes it and easily reduces it to powder. The softened tissue of the roots can be penetrated through a certain thickness.

The protected teeth show upon their exposed points of enamel the same change as is seen in the exposed teeth; except that the action, limited to the enamel layer, has respected the subjacent ivory (Fig. 15, B).

Exp. II. — Solution of one part in one hundred: butyric acid

two grams, water two hundred grams. The teeth show the same change as before, but in a much greater degree, so that the enamel is removed without the least effort, and the roots, softened throughout their length and thickness, are flexible as gelatine. The general color of the whole is yellowish, resembling the color produced by lactic acid, with the exception of the enamel which has become white and opaque.

*Conclusions.* — Butyric acid resembles lactic acid in its action, — in its mode, the rapidity of the change it produces, and the coloration it causes upon the tissues. It is, moreover, fixed and insusceptible of fermentation, as is indicated by the condition of the liquid both before and after the experiment. Its influence is therefore common upon the whole body of the dental tissues.

To butyric acid we must compare other agents of the same chemical series, $C_n H_{2n} O_2$, valeric and propionic acids, whose action is evidently the same, but whose presence in the mouth is too rare for us to attribute to them any active part in the production of dental caries.

### (*d.*) Citric Acid.

Exp. I. — Solution one part in one thousand, or one gram of citric acid to one liter of water. After two years the solution has kept its transparency and its primitive acid reaction. A thick mildew has formed upon the surface.

The teeth left freely exposed at the bottom of the glass are covered, and, so to speak, enveloped in mammillated, whitish growths which are nothing but citrate of lime. They are almost entirely deprived of their enamel, of which there are only traces at several points, the rest having gone to form the masses of citrate of lime. The roots and the points of the crown, deprived of their enamel, are softened generally and throughout their substance, but without special coloration, so that at first view it might be thought that both enamel and cement had escaped

without change. The teeth protected, except at a point of their enamel, present at this point the same alteration, together with

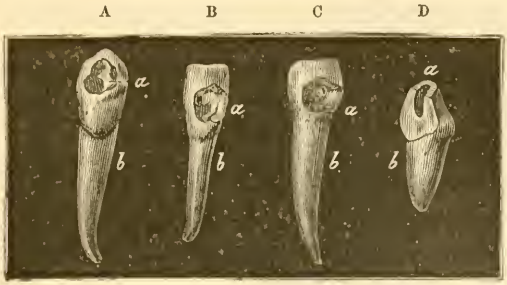



Fig. 15. Four Carious Cavities developed upon the Crowns of Teeth protected with Wax except at one point. A. Caries from citric acid. B. Caries from butyric acid. C. Caries from malic acid. D. Caries from cider.

formation of stalactites of citrate of lime, produced at the expense of the whole thickness of the exposed portion; and the ivory, equally attacked by the liquid, has undergone a profound softening, without detachment of the altered parts, these retaining their positions, but gelatinized.

Exp. II. — Solution of one part in one hundred: citric acid two grams, water two hundred grams. This solution, like the preceding, has changed neither in appearance nor reaction. A thick grayish mould covers the surface of the liquid. The teeth left exposed are completely deprived of enamel, the whole being transformed into masses of citrate of lime and deposited in layers at the bottom of the vessel.

The teeth thus reduced to their ivory and cement have undergone no other apparent loss of substance, nor any change in appearance or in color; but taken between the fingers they are found to be flexible, spongy, and gelatinous.

The teeth protected by wax show at the exposed points of their crown a local destruction of the enamel, whose whole thickness has gone to form a mass of citrate of lime (Fig. 15, A). The alteration has even spread laterally under the borders of the perforation in the coating of wax and extended

to the neighboring portions of the enamel, which have become opaque and to some extent chalky. Below the ivory is softened to a considerable depth and is easily penetrable by a sharp-pointed instrument.

*Conclusions from the Experiments with Citric Acid.* — In our experiments citric acid appears not to have fermented; it has therefore acted of itself and without further transformation. Its action is common and uniform upon all the dental tissues, and its destructive influence is so energetic that the effect had already been produced with considerable intensity hardly two months after the beginning of the experiment. It may therefore reasonably be asserted that of all the substances that act upon the tooth as a whole, there is no one among the conditions of our experiments and the circumstances of ordinary alimentation possessing a more pernicious influence upon the teeth. Moreover it acts without change of aspect or of color in the altered parts, which leads to the conclusion that its nature is to produce the white caries. From this is seen the dangers that may result from the too frequent use of certain fruits, such as oranges, lemons, limes, mandarins, which owe their savor and their acidity to this agent, and the prolonged use of lemonades, orangeades, etc.

### (*e.*) Malic Acid. — Cider.

Exp. I. — Solution of one part in one thousand: malic acid one gram, water one liter. The solution has changed neither in color nor appearance; its reaction remaining clearly acid. A grayish and heavy mould floats upon the liquid.

The exposed teeth present a complete opacity of the whole enamel layer, which is friable and chalky but not removed from its position or detached from the surface of the ivory. The

roots are uniformly softened nearly to the center, but without becoming either flexible or gelatinous.

The protected teeth upon the exposed points have undergone the same change (Fig. 15, C), a chalky condition of the enamel and softening of the subjacent ivory to some depth.

Exp. II. — Solution of one part in one hundred: malic acid two grams, water two hundred grams. The appearance and color of the liquid have not changed; a thick mould covers the surface.

The teeth exposed and protected present the same alteration in character as in the case preceding, but with an intensity proportioned to the strength of the solutions, that is, 10 to 1.

Exp. III. — With these two experiments we should mention another with cider, which owes its acidity, as is well known, to malic acid, and to which has been attributed, for certain regions of France, an influence upon the condition of the teeth of their people who use this exclusively as a drink. This experiment begun in 1864 was made with one liter of Normandy cider of 1863, having all the characteristics of this drink; reaction clearly acid, taste sour, insipid, and a little bitter; drawn directly from the cask there was no gas.

Two groups of teeth were placed in the liquid and have been left in it for two years. The first consisted of three sound teeth, weighing together two grams, 54 centigrams; the second consisted of two teeth likewise sound, and protected with wax except at a point of the enamel.

At the end of the experiment, the liquid was gaseous, but still preserved its acid reaction to litmus paper. The other characteristics were those of cider which has been long bottled. The group of exposed teeth weighing two grams, fifty-four centigrams has fallen to one gram, twenty-two centigrams, and consequently has lost one gram, thirty-two centigrams of its weight; the whole enamel is opaque, friable, and chalky, yielding with great ease and falling into powder upon scratching with the nail. The roots are softened, flexible, and pene-

trated with a general clear brown tint which contrasts with the dead white of the crown enamel. Of the two protected teeth, one (an upper central incisor) exposing as its denuded point the free edge of the crown deprived of its enamel by wear, presents a very marked softening of the ivory, which has become yellow and shows every characteristic of veritable caries (Fig. 15, D). The second, an upper canine, exposed upon the centre of the anterior face of the crown, has undergone at this point no appreciable injury. This latter circumstance is due, as in every such case we have met, to the extreme resistance offered at this point by the enamel, which also explains the rarity of caries at this point.

*Conclusions from the Experiments with Malic Acid and with Cider.* — Malic acid is a fixed acid whose action is common and uniform on all the dental tissues. The intensity of its action is nevertheless variable in the three preceding experiments; its maximum was reached in the one per cent. solution of malic acid. The least active was the solution of one part in one thousand, the cider occupying an intermediate position. Several practical results follow from these experiments: first, the injurious effect of certain fruits, apples, pears, quinces, etc., which owe their acidity to malic acid. Finally, the influence, so much discussed, of cider, here finds its complete experimental demonstration; the loss of substance by the teeth plunged directly in this liquid, as well as their profound and general softening, are entirely convincing proofs. Cider is therefore pernicious to the teeth, and here, perhaps, we find a part of the explanation of the habitual caries in individuals addicted to the free use of this drink, the Normands, for example. The experiments with cider had occupied our attention for a long period, and several years ago, in Normandy, we had, by means of floats, placed groups of

sound teeth in casks of cider kept constantly filled. The teeth, sought for after two or three years in the casks, could never be found in spite of the most minute search. At that time we dared not believe in so energetic an action of cider as to cause the disappearance of every trace of the teeth experimented with. These later results, however, prove that such action is possible, and it is the better explained in that the cider kept in casks is generally much more acid than that which has been bottled. A second element which may come in in the question relating to cider, is the presence of carbonic acid in the gaseous ciders. Our direct experiments with carbonic acid will sufficiently answer this, and this influence will, moreover, be exclusively confined to the bottled ciders, that kept in barrels, always incompletely corked, not being capable of containing more than a very minute volume of this gas.

### (*f.*) Carbonic Acid.

Ancient experiments of Berzelius and of Dumas had established that plates of ivory plunged in Seltzer water were softened in the same manner and as rapidly as in weak hydrochloric acid. With the purpose of verifying these facts we instituted the following experiments: —

Exp. I. — Seltzer water made directly in an ordinary gasogene apparatus, that is to say, about one volume of water to five of gas.

The results indicated have been fully verified. At the end of a week thin plates of ivory cut from a hippopotamus tusk were softened and flexible; sound human teeth had undergone a marked alteration in their substance and a loss in weight, to the amount of about a tenth; the ivory of the root could be pierced with a sharp instrument and the enamel had become friable and chalky.

Exp. II.—In a second experiment we submitted preparations to the action of a solution of carbonic acid open to the air, that is to equal volumes of water and gas. The contact lasted also a week, and at the end of this time the laminæ of ivory and the teeth had experienced no loss of their weight nor undergone any apparent alteration.

*Conclusion.* — Carbonic acid at the pressure of five or six atmospheres, as in Seltzer water, exercises upon the teeth the action common to the weak mineral acids, but in equal volumes its influence is entirely *nil.* What, from the point of view taken by us, is the rôle of this agent, nowadays so common? Should we consider it, in the form of Seltzer water, as the destructive agent for the teeth which our direct experiments would seem to indicate it? We think not. It should be remarked that, in fact, if Seltzer water when first drawn is at a pressure of five atmospheres, it falls rapidly in the open air and in contact with the temperature of the mouth, to one or two atmospheres and even below, at which degree of concentration no injurious action can go on in ordinary conditions; moreover, the passage through the mouth is rapid and insufficient to permit any influence whatever.

Another question which occurs here as to the action of carbonic acid, is as to the possibility of its action when produced spontaneously in certain fermentations in contact with the teeth, fermentations of the albuminoids, for example. In this latter case the carbonic acid in solution in the substances in and from which it is formed is still below the proportion of equal volumes, and, even admitting a very prolonged contact, cannot, in our opinion, contribute to the production of caries.

### (*g.*) Albumen and Albuminoids.

Exp. I. — Solution composed of one liter of water to the whites of two eggs well shaken in the liquid. The experiment lasted two years. After this time the solution became yellowish and clouded; numerous flocks of mould floated in the liquid which showed a manifest acid reaction and had an extremely fetid odor.

Teeth left freely exposed in the vessel have undergone a general and uniform softening; the roots have become translucent and soft, the enamel friable and opaque. One of these teeth, which had a very deep furrow in the centre of its crown, has at this point an extremely large excavation, in which seem to be deposited the débris of albuminous shreds which have there, in position, undergone the most advanced putrefaction (Fig. 16, B). This excavation, soft at the bottom, uneven and fragile at the borders, presents every characteristic of true caries.

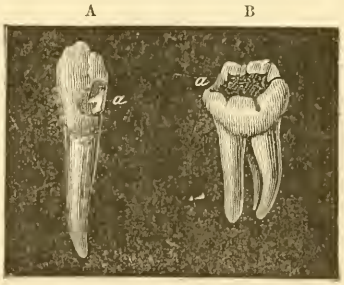



Fig. 16. Two Cases of Artificial Caries developed in Albumen upon points left exposed in a covering of wax. A. Caries of the anterior face of the crown of an adult incisor. B. Caries of the masticating surface of a molar.

The protected teeth have undergone upon the exposed points a similar effect; one of them, exposed upon the most resistant part of its enamel, has experienced but a slight alteration resembling the beginning of caries (Fig. 16, A). Another tooth, exposed upon the free edge deprived of enamel, has there experienced a softening still more pronounced, which has resulted in the formation of a cavity in the form of a deep cleft, with every characteristic of caries properly so called.

*Conclusions.* — Albumen and all albuminoid substances whatsoever, whose action we may consider as uniform,

can of themselves effect no alteration of the teeth. Therefore it is only by the results of their fermentation that these effects can be produced. Now, left to themselves, these substances enter upon putrefaction and the formation of the heavy acids of the acetic and benzoic series. The elements drawn from this latter series need not occupy us, for they are evidently without any possible alterative action. In the acetic series, on the other hand, are found butyric acid, whose manifest influence we have studied by itself, and valeric acid, identical in its action with the foregoing, and some other analogous derivatives. These acids have clearly been produced in our experiment, the reaction of the liquid sufficiently indicating the fact; and further the extremely fetid character of the odor of the solution recalls that of the butyric and valeric acids.

Albumen and the albuminoids are, therefore, by the elements of their alteration, able to exert a destructive action upon the dental tissues. Now, there is nothing more frequent than the prolonged stay in a dental interstice of débris of albumen, fibrine, caseine, which there putrefy at their ease, giving the breath the special fetidity of these kinds of alterations, and, if the same or a similar substance is frequently renewed at the same point, bringing on caries.

The albuminoids have besides, a second influence not less important from our point of view, namely, that they are capable of acting as ferments upon a great number of other substances, so that in an interdental mass, composed of particles of various kinds of food, there may be found at the same time, those which are fermentable and those which can act as ferments, — a circumstance which gives to a region of this kind a doubly important

influence, and permits us in practice to attribute a very salutary influence to the proper care for the cleanliness of the mouth, especially after partaking food.

(*h.*) Alum, 1 part in 100.

Exp. — One solution only has been experimented with in the proportion of ten grams of alum in a liter of water. After two years the liquid remained clear, was inodorous, transparent, and contained numerous grayish mouldy flocks throughout. Reaction clearly acid. The teeth left free in the solution are not at all affected in their roots, which present neither softening, nor any change of color or of form. The enamel through the whole extent of the crown is greatly altered; it has entirely lost its glassy look, and has become opaque; its disorganization is such that it has the appearance and the brittleness of a layer of chalk; it is detached by the least effort from the subjacent ivory and falls in a white powder. (Fig. 17, A.)

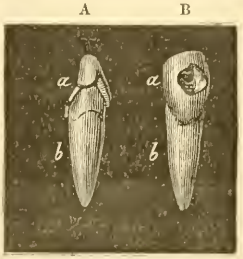



Fig. 17. Artificial Caries from Alum. A. Special alteration of the whole layer of enamel of an incisor left freely exposed in the liquid. B. Limited caries of the enamel layer, developed upon a point of the crown covered with wax except at this point.

The protected teeth upon the denuded points of their crowns show an identical alteration of the enamel. Two of them, exposed upon a depression in their surface, show a complete destruction of the enamel, but without passing the limit of the exposure. A third, an upper bicuspid, exposed upon the most resistant point, the anterior face of the crown, has undergone a change of the same kind, but without penetrating the whole thickness of the enamel.

These teeth, therefore, show all the characteristics of caries of the first degree, opacity and friability of tissue, loss of polish, separation of prisms, etc.

*Conclusion.* — Alum, a mineral substance slightly sus-

ceptible of fermentation, respects absolutely the ivory and cement of the teeth, and destroys with great energy the elements of the enamel. It must therefore be an exclusive alterant of the latter; as to this singular action we confine ourselves to recording it without endeavoring to furnish the explanation, leaving this to the chemists. We will say, nevertheless, that the reactions caused by its contact with the teeth are the formation of sulphates of alumina and of lime. But why this special effect upon the enamel and none upon the ivory ?[1]

### (*i.*) Bi-oxalate of Potassa.

Exp. I. — Solution of one part in one thousand: water 200 grams, bi-oxalate of potassa 0.20 gr. Solution has remained clear, transparent, inodorous, containing some mildew at the bottom of the vessel. Neutral reaction with litmus test paper. The freely exposed teeth and those exposed only at a point of their surface have undergone no manifest change.

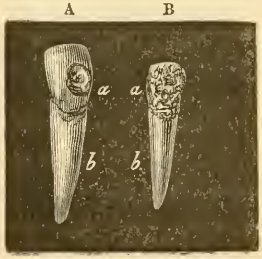



Fig. 18. Artificial Caries produced by Bi-oxalate of Potassa. A. Caries upon an exposed point of the enamel of a protected tooth, *a*. B. Tooth entirely exposed in the solution. Its crown at *a* showing a complete destruction of the enamel, at *b* the root intact.

Exp. II. — Solution of one part in one hundred: water 125 grams, bi-oxalate of potassa 1.25 gr. The liquid has remained clear, transparent, without mildew, inodorous. Reaction acid. The teeth freely exposed show no change on their roots, which have preserved all their characteristics ; but the enamel has been disorganized throughout; it is opaque, friable, and is very readily removed and reduced to powder by an excavator. (Fig. 18, B.)

The protected teeth have experienced at their exposed points an identical alteration (Fig. 18, A). It is also to be remarked that this alteration has not been limited to the uncovered point,

[1] See note on p. 155.

but has spread to and affected the greater portion of the enamel layer by slow penetration beneath the layer of wax, or by propagation from point to point in the tissue of the enamel itself.

Another tooth from the mouth of an aged person, exposed on a portion of the masticating surface, at a part entirely deprived of enamel by wear, has not at this point undergone any softening; nevertheless, the liquid having penetrated beneath the wax, has slightly disorganized the neighboring enamel.

*Conclusion.*—The bi-oxalate of potassa has an effect very like that of alum, with not quite its intensity, appearing, like it, to act exclusively on the enamel. As this salt has a fixed composition and is not susceptible of fermentation, it is evident that oxalic acid and all the acid oxalates would show the same results. These experiments explain the phenomena of the "setting on edge" especially produced on the enamel by the use of certain alimentary substances rich in oxalates, as tomatoes, the sorrels, etc., and the injurious effects which their frequent use may have upon the teeth.

### (*j.*) Acetic Acid.

Exp. I. — Solution of crystallizable acetic acid of one part in one thousand: one gram to one liter of water. The liquid at the end of two years has remained limpid and transparent with a slight deposit of mould and another layer at the surface. Yet the reaction of the liquid is neutral. Neither the teeth freely exposed nor those protected appear to have undergone any alteration.

Exp. II. — A solution identical with the foregoing, with the addition of some drops of creosote, has given the same negative results.

Exp. III. — Solution of one part in one hundred. Water two hundred grams, acetic acid two grams. The liquid, after two years, has remained limpid, transparent, of an acetic odor;

no mildew; reaction clearly acid. The teeth experimented with at the bottom of the vessel are covered with a minute, brilliant, crystalline deposit.

The teeth freely exposed show a peculiar alteration; the roots are deeply softened, have become flexible, yellow, considerably thinned out in the direction of their length, whilst the crown has experienced no modification. The enamel, which presented primitively no imperfection nor solution of continuity, has lost nothing of its polish, its appearance, or of its resistance. These phenomena have given to these teeth the curious appearance of a normal crown surmounting a kind of peg (Fig. 19). At the neck the alteration of the ivory of the roots, having penetrated beneath the enamel of the crown, has isolated and left it without support, having itself experienced no effect. A fragment of bone has also become softened and considerably reduced in volume.

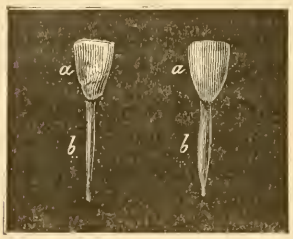



FIG. 19. Artificial Alterations from Acetic Acid upon Incisors freely exposed; *aa*, crowns intact; *bb*, roots reduced and softened in the direction of their length, and become unrecognizable.

*Conclusions from the Experiments with Acetic Acid.*— In a weak solution in the proportion of 1 to 1,000, acetic acid exerts either no action or but a very slight one upon the teeth; in a stronger solution of 1 to 100, it remains entirely without action upon the enamel, but vigorously attacks both the cement and the ivory. The consequence from these facts, from a practical point of view, is that, employed with food in the form of vinegar it can exert no injurious effect upon the teeth, conditionally that these have kept their enamel intact and have no exposed point either of the ivory or of the cement. But if the enamel is wanting at any part, either through acci-

dent, or from caries or wear, the use of vinegar may be injurious. We see, in fact, that teeth in these latter conditions upon contact with this agent experience a sensation of irritation which becomes at times a real pain.

The fact itself of the alteration undergone by the cement and ivory of teeth exposed to acetic acid is explained by the property this agent has of dissolving the earthy phosphates, a property singularly favored, according to Dehérain,[1] if they are found in the presence of carbonic acid or the carbonates, as is precisely the case with the ivory and bone. As to the integrity preserved by the enamel, it is owing perhaps to a smaller proportion of the phosphates, and doubtless also to the minute quantity of fluoride of calcium it contains, or perhaps to certain combinations of these substances of a nature calculated to resist all alteration.

### (*k.*) Tartaric Acid and Acid Tartrates.

Exp. I. — Solution of one part in one thousand: tartaric acid one gram, water one liter. The liquid has not changed its appearance, contains some mould; is inodorous, reaction neutral. The freely exposed teeth appear to have undergone no appreciable alteration.

Exp. II. — Solution of one part in one hundred: tartaric acid two grams, water two hundred grams, some drops of creosote. The freely exposed teeth show no change on their crowns; the enamel is simply covered with a layer of crystals, but remains absolutely intact. The roots, without being generally or deeply softened, have yet undergone a real alteration in their substance; the excavator, by scratching, can remove quite easily the whole layer of cement and pierce to some depth the layer of ivory which has, nevertheless, preserved its color and its usual translucency.

[1] Cited by Pelouze & Fremy, *Traité de Chimie*, p. 590.

The protected teeth, as they exposed to the liquid only a single point of enamel, have experienced no effect.

Exp. III. — Solution of tartrate of potassa, one part in one thousand: cream of tartar, one gram of the salt to one liter of water. The liquid is slightly clouded, with a great mass of floating mould, inodorous, neutral. Neither the exposed nor the protected teeth have undergone any alteration.

Exp. IV. — Solution of bi-tartrate of potassa, one part in one hundred, or two grams of the salt in two hundred grams of water. After two years the salt has not entirely dissolved. The liquid is transparent, inodorous, covered with a thick mould; reaction clearly acid.

The teeth are covered with an abundant crystalline deposit strongly adherent to the surface. The enamel nevertheless shows no alteration, the roots show a superficial softening of the same kind as that produced by tartaric acid, but with an intensity slightly less. The only points of enamel offered to the liquid by the protected teeth show no signs of alteration.

*Conclusions from the Experiments with Tartaric Acid and the Acid Tartrates.* — Tartaric acid and the acid tartrates, without appreciable action upon the enamel, effect upon the cement of the roots and the subjacent ivory a softening which without penetrating the entire root, progresses to a certain depth, after the manner of acetic acid. They may therefore be considered with it as special agents of alteration and limited in their action to the ivory and cement. The peculiar action of tartaric acid upon the teeth should be regarded as a solution of the phosphates, at least at the ordinary temperature; for this acid, subjected to the warmth of the mouth, may lose its fixity and enter upon fermentation, giving rise to the series of heavy acids, acetic, butyric, propionic, etc. As for the acid tartrates contained in wines and especially in very many fruits, their action

should be considered as direct, in their quality of fixed salts, and, in every case, their fermentation, very little known, appears to be analogous to that of tartaric acid, which ferments only in the saline condition and in the direction of the acetic, butyric, etc., series.[1]

### (*l.*) Chloride of Sodium.

Exp. — Solution of one part in one hundred: chloride of sodium (common salt) with the addition of three drops of creosote. The liquid after two years has not sensibly changed its appearance; it is yellowish, slightly clouded, without mould, neutral, but has formed upon the bottom of the glass and on the surface of the preparations a slight deposit of a dark shade. The teeth freely exposed have undergone no alteration of their substance, except that they have taken a dark color generally and especially intense in the root. This color does not appear to result from any deposit at the surface of the tooth simply, but from a thorough penetration by the coloring matter of the whole tissue. In fact scraping does not remove it, and a thin section shows under the microscope the canalicules filled with very minute amorphous granulations which should be looked upon as coming from some impurities in the salt, from a ferrous deposit perhaps.

The protected teeth, having but a single point on the enamel exposed, have experienced no special change, except a slight dark deposit of the same kind but very easily removed by scraping, and which has not penetrated the tissue of the enamel.

*Conclusion.* — Chloride of sodium is without action on the teeth. Nevertheless its presence, so frequent in our food, may account for those dark deposits observed in certain individuals, aside from some special causes,

[1] See Pasteur, *Comptes Rendus de l'Acad. des Sciences,* vol. lvi., p. 1193. 1863.

such as tobacco, and the medicinal preparations of iron and manganese.

This negative result is in opposition to the experiments of Lassaigne,[1] who has asserted that saline solutions of chloride of sodium, and other salts of like character, are able to dissolve, in notable proportion, the calcareous phosphates. This, at least, seems not to be the fact as regards the teeth.

(*m.*) Tannin.

Exp. I. — Solution of one part in one thousand: one gram of the tannin of commerce in one liter of water. The liquid, reddish and turbid, has not sensibly changed in appearance. It is covered with a heavy, thick coat of mould; the reaction, at the outset scarcely acid, has not varied. The teeth, whether free or protected, have undergone no manifest alteration.

Exp. II. — Solution of one part in one hundred: tannin two grams, water two hundred grams. The liquid has preserved, after two years, its yellowish color, its clouded aspect, and its clearly acid reaction. A heavy, thick mould floats upon it.

The teeth freely exposed show no appreciable alteration in their enamel, which is merely covered with a light deposit of a greenish coloring material, but has kept its polish and its ordinary hardness. The roots show a marked softening of their substance, which is at the same time stained a light brown color, and can be penetrated by an excavator to some depth.

The protected teeth have undergone no alteration at the points of their enamel left exposed.

*Conclusion.* — Tannin is a special alterant for the ivory and cement, its effects being probably produced by previous fermentation with fermentation of the derived acids; but its action, which is produced only at a considerable degree of concentration, need not, in our

[1] *Traité de Chimie.*

opinion, receive any very important application in the pathogeny of dental caries.

### *Résumé of the preceding Experiments.*[1]

If this series of experiments is examined in their general character we perceive that the agents experimented with may be divided into four groups: —

1st. Those which act uniformly upon all the dental tissues: such are: the sugars, by their products of fermentation; the lactic, butyric, citric, and malic acids; cider, carbonic acid, the products of putrefaction of albumen and albuminoid substances.

2d. Those which disorganize the enamel specially and exclusively with formation of salts of lime insoluble in the acid liquors: alum, oxalic acid, and the acid oxalates.

3d. Those which act specially and exclusively on the ivory and bone with formation of salts of lime, soluble especially in the acid liquors: acetic acid, tartaric acid, and the acid tartrates, tannin.

4th. The substances wholly without action on the teeth, as chloride of sodium and generally all other substances which may be met with in the buccal cavity, soluble in water and the saliva with neutral or alkaline reaction.

With regard to the agents used by us in direct experiment, without prejudging the possible action of many others which may be found in accidental contact with the teeth, it must be remembered that the facts collected relate simply to the most ordinary circumstances of alimentation, to the habitudes and usages of the mouth.

There remains, then, a wide field of study for the in-

[1] For a review of these experiments, see Leber and Rottenstein on *Dental Caries*, pp. 74–87 of my Translation. — Tr.

vestigation of the influences which other substances may exert upon the teeth. Nevertheless we should take account of certain results already ascertained: thus, we have not mentioned the general action of the mineral acids, already known as in the highest degree disastrous to the dental organ, but which, by reason of their rare presence in the saliva, we have not dwelt upon. These facts, well known, were long ago ascertained by Dr. Regnart.[1] Other facts have been likewise collected by different observers: thus, the investigations of Dr. Brown tend to establish that certain preparations of iron employed in medicine tend to injure the teeth; such are the solutions of chloride of iron, the perchloride, the sulphate; while the carbonates, the phosphate, and the iodide of iron, and the sulphate of quinine, are without action.[2] These results, presented, it is true, rather hastily and without sufficient exactness, may demand an attentive examination. Nevertheless, we do not attach any great importance to them, for the use of these substances, like that of the mineral acids, is relatively too infrequent and their passage through the mouth too rapid.

Another point made clear by our experiments is the fixation of the point of concentration, corresponding to the possible action of the various substances experimented with; thus, while lactic, tartaric acids, etc., have but a feeble action in a solution of one part in one thousand, that of citric acid at the same degree of concentration is very powerful. These differences are useful to note in the practical interpretation of the effects of these agents when brought into contact with the teeth.

The nature of the alterations undergone, at one time

[1] *Recherches sur la Carie Dentaire*, 1838, p. 13.

[2] *British Journal of Dental Science*, 1864.

general to all the dental tissues, at another special upon one or another tissue, lead at once to certain practical consequences. Thus, a tooth, otherwise perfectly intact, may experience upon some point of its exposed surface, and in a regular manner, caries produced by the agents of the first group; if the enamel preserves its integrity it may succumb to the action of substances which act exclusively upon enamel; while, to experience the action of the substances specially acting on the ivory, it is necessary that the enamel should be wanting at some point, or else that the neck or the root of the tooth be denuded. This is exactly the case with those teeth whose enamel has been worn away by the progress of age,[1] or separated by wasting from the gums and the alveoli covering them. They become, in such cases, liable to the influences of substances of this order, as vinegar, the tartrates, tannin, etc. We shall not insist upon these various peculiarities belonging to the mechanism of the production of dental caries.

As for the explanation of these exclusive actions, we must confess it escapes us. We may without doubt find it in the various relations to one another presented by the physiological combinations of the mineral and organic substances in the different tissues composing the tooth, and also in the disposition of the elements constituting them and the peculiarities of their chemical composition.

§ 4. *Mechanism of the Production of Dental Caries.*

After the explanations given in the foregoing paragraphs it will be understood that, in order to comprehend the mechanism of the formation of caries, it will suffice

[1] Or by the file. — Tr.

to make a simple application of the acquired ideas to the particular cases in which this malady takes place in the mouth.

It is perfectly established that dental caries results from a direct alteration of the organ by means of substances which originate in the saliva, or are accidentally introduced, an alteration usually preceded and favored by certain congenital or acquired predispositions of structure or of anatomic conformation. These predispositions have indeed so great an importance that, all other conditions being equal, if the teeth of a given individual present an irreproachable perfection both of form and texture, they will be able entirely to resist any more or less energetic temporary cause, and even a prolonged influence, whilst others, smitten by an hereditary vice of conformation, or with defects in their substance by accidental circumstances, are predestined to caries and prematurely undergo complete destruction.

A second point to which we should likewise recur in our examination of the mechanism of caries is this singular specialization of certain substances upon one or another dental tissue, so that side by side with agents which attack the teeth in their totality and in a uniform manner, there are others which attack the ivory only, and still others which act only upon the enamel. The consequences of these different actions are important to note. Let us suppose, for example, that a tooth, intact as to its enamel, and whose neck is wholly protected by the gum, be exposed at a given moment, in the mouth, to the exclusive and prolonged action of an agent specially active against the ivory, acetic acid, for instance; such a tooth will undergo no modification whatever. If on the other hand we take an agent which attacks the enamel

alone, such as alum, the alteration will be eminently rapid and energetic, but will confine itself to the enamel. Finally, if the influence of the destructive agent is common to all the dental tissues, the alteration will be uniform, gradual, and continuous, which is indeed the most frequent case. Let us also consider in a general way the case of a dental interstice, or a natural crevice whose enamel is as yet intact; what will be the exact phenomena shown by the tooth if there is exhibited an agent active against the whole of this organ? A minute mass of various substances, alimentary débris, mucosities, etc., having the peculiar composition whose description we have already given, becomes the place of development and the receptacle of an active substance which thus finds itself in immediate contact with the surface of the tooth. Now if this has preserved its original integrity it opposes at first its *enamel cuticle*, an amorphous, very resistant membrane, endowed with great tenacity and adhering perfectly to the surface of the enamel. This cuticle, which subsists to adult age, except at the free border of the teeth, where it is speedily worn away by friction, may nevertheless, as well as the other constituents of the dental organ, have certain imperfections of structure, some congenital solutions of continuity which offer an easier passage to the agents of caries. Yet if we suppose it intact, the acid element in whose contact it remains has the effect of softening it little by little, and of penetrating it, so that, arrived below it, the acid produces a slight decomposition of the enamel, a slight disengagement of bubbles of carbonic gas, which raise and soon perforate it. This phenomenon is exactly comparable, save a lesser degree of energy, to that which reveals the existence of the normal cuticle at the surface of the enamel, where upon a section for microscopic ex-

amination we introduce a few drops of hydrochloric acid; the membrane then raised by the bubbles of gas becomes detached and floats free in the liquid.

When this cuticle has been thus detached from the surface of the teeth, the alteration begins on the enamel itself. It begins with a separation, a dissociation of the prisms, whose interstices lose their transparency and are filled with liquids and granulations. Little by little the destruction goes on until the whole mass, corresponding to the point left uncovered by the loss of the cuticle, presents to the eye a chalky and brittle appearance, representing the first degree of caries. This action, beginning at the external surface of the enamel, pursues its way in the direction of the prisms, which it gradually destroys throughout their length, reducing them at last to a fine and white powder, which soon falls away, and gives rise to a cavity through the more or less considerable disappearance of prisms, and whose depth is measured by a part or the whole of their length.

The alteration from the chemical point of view consists, as concerns the enamel, in a separation by the altering agent between the organic substances and the mineral elements in their physiological combinations. The organic matter, in very small proportion in this tissue, is removed rapidly, and insoluble salts of lime, lactates, citrates, butyrates, sulphates, etc., are the results. This mechanism of alteration of the enamel is uniform for all the agents which act exclusively upon this tissue or commonly upon the whole dental organ; yet, in the first case, when the alteration has penetrated its whole thickness, it arrives at the surface of the ivory, where it remains henceforward inactive and unable to penetrate farther towards the centre of the tooth. There remains to it, however,

the possibility of spreading laterally and of causing from point to point the superficial destruction of a portion and sometimes even of the whole of the enamel. This is what happens after a prolonged use of alumminous preparations, of citric lemonades, of dentifrices of special composition, etc., the final result of which is the formation of caries of the first period.

The agent of alteration of the caries, the enamel layer having been attacked and removed, finds itself in contact with the ivory which offers to it its special organization, its anastomosed canalicules, its composition richer in organic material, and consequently more penetrable. The first point met is the layer of minute cavities of communication which we have designated by the term *anastomotic plexus* of the dentinal canalicules. The fluid that fills these cavities, and the canals immediately succeeding them, mixes with that coming from the exterior loaded with altering principles, and a veritable imbibition into the mass of ivory rapidly takes place. Now, it results from this imbibition that the influence of the active substance is exerted upon an extent of the ivory measured by the developed surface of the canalicules and their anastomoses, which explains how, in this tissue, caries progresses ordinarily much more rapidly than in the enamel, leaving out of account the special phenomena of resistance peculiar to the ivory, which we have hereinbefore examined, whilst the enamel passively submits to the decomposition of its elements. The destructive agent, carried thus into the very heart of the ivory, effects the reduction of its mineral phosphates and carbonates, which pass to the state of soluble salts, and sets them free from the organic materials previously combined with the mineral elements. This organic matter, softened and become

gelatinous, is not always carried away with the newly formed calcareous salts, but often remains at the bottom of the carious cavity, forming by its sponginess a focus for new fermentations and a permanent agent of progression of the malady. Such are the gelatiniform masses arranged in layers at the bottom of the cavities, which have a marked acid reaction when triturated with a little distilled water. They have sometimes a considerable thickness, equaling, even in a cavity of small diameter, the whole thickness of the ivory. The softening nevertheless decreases gradually as we approach the centre, but in some cases it even reaches the surface of the pulp, where it sets up inflammatory symptoms; so that caries even of apparently little depth may already give rise to severe pains.

By reason of these various peculiarities it may be said with truth that if an alterant encounters in the enamel, whether through its protecting cuticle or through the resistance of its own elements, serious obstacles to development or progress, it is not so with the ivory, where the phenomena of resistance, in order to triumph over the dispositions more favorable to alterations, ought to be endowed with great energy. Thus the number of cases of dry caries, that is to say, of caries arrested or cured spontaneously by these acts of resistance during the second period of the malady, is small compared with the considerable number of those which proceed regularly and fatally to the end, causing little by little the total loss of the organ.

The two modes of development and progression of caries in the enamel and in the ivory sum up the complete mechanism of formation of the malady, and are applicable to every case, whatever may be the various causes and conditions which otherwise govern its character.

These are in fact the same phenomena which take place, sometimes in the hardened masses of mucus that cover the surfaces of the teeth habitually and normally in some subjects, sometimes in the midst of concrete masses observed in the mouth during the course of acute diseases, sometimes also in the very saliva that bathes the teeth during the period of chronic affections or diatheses, so that, whether the caries represents an accidental affection and is limited to one or several teeth, or if it is general or nearly so to all the teeth of one individual, the nature of the malady remains the same, with simple differences of the energy and duration of action of the productive cause. One very interesting peculiarity of this story ought to arrest our attention, namely, the *contagion* of caries, not indeed its propagation from one subject to another, but its passage by direct contact from a preëxistent caries to a contiguous sound tooth.

It has been always agreed that a carious tooth generally brings after it the alteration of its neighbor, on condition that the two teeth are in actual contact, for every interval, however small, neutralizes this contagion. Thus it is observed that commencing caries, developed in this manner, very often stops of itself if the tooth originally affected is extracted or simply cured. The simultaneously occurring caries on opposite sides of the same jaw or on different jaws are not due to contagion. We have elsewhere explained the facts appertaining to the conditions of conformation and of structure, reproduced identically in the two teeth in consequence of their simultaneous development under the control of the same influences.

As to the mechanism of propagation by contact, it differs in no respect from that which governs the first alter-

ation. When a destructive agent, exercising its action in a dental interstice, has not, as often happens, produced at the outset two equal and simultaneous alterations, the caries, after having excavated a cavity in one of the teeth, becomes for the neighboring tooth, as for itself, a centre of fermentation of the most active kind, and the same phenomena of internal decomposition shown by the first are exactly reproduced in the second.

Caries regarded from this point of view consists then precisely in a simple solution of the calcareous salts of the dental tissues by an acid element developed or brought in contact with them. Such is the rigorously logical conclusion which seems to us to result from all the considerations and experiments just stated. Other secondary phenomena are sometimes produced concurrently about the altered parts, and have by various observers been held to a certain degree responsible. It is thus that putrid decompositions, which have especially for their source débris of animal or vegetable substances of alimentation, have been invoked;[1] in like manner the cryptogams and vibrios, whose formation we have regarded as an epiphenomenon of the malady, have been considered as agents of the alteration by Ficinus,[2] thus taking precedence of the theories of M. Pasteur.

In another doctrine, M. Oudet[3] considers caries as an organic disease proper to the tissue of the tooth, developing itself in the centre of the organ and finally coming to light at the exterior, whilst other purely chemical alterations are regarded only as changes of a different nature from the caries properly so called. We have already

[1] Kölliker, *Histologie Humaine*, French Translation, 1856, p. 440.

[2] *Journal für Chirurg.*, Walther and Ammon, 1846.

[3] *Dictionnaire en Trente Volumes*, article *Dent.*

said that no observation has ever demonstrated the existence of internal caries, and that it is always provided with an external orifice, often difficult to perceive but always provable. We will discuss no farther these questions, which all the facts of our examination will easily answer.

If now, in bringing this long etiological survey to an end, we regard in a general way the conditions that favor and provoke the development of caries, we are struck with the great number and complexity of the causes governing the production of this malady, whilst the real agent stands out clearly, showing in its action a constant fixity and invariability. Thus the salivary liquid and the buccal mucus may, with conditions of perfect health and in the physiologic state, unite the formative elements of caries, which then appears without appreciable immediate cause, and as the result solely of primordial and natural predispositions, to which are added the primitive conditions of conformation and structure of the teeth themselves. It is thus that we may explain the caries of so rapid and general a character, which sometimes occurs in infancy without any previous disturbance of the health to account for it; also those which are, so to speak, endemic among certain populations. We have heretofore seen how many explanations have been proposed of these facts of caries so generalized: the use of water, hard or at a very low temperature, the neighborhood of the sea, of rivers, or of swamps, without any direct relation rationally established between the appearance of the malady and these presumed influences. Caries, a local affection *par excellence*, obeys an agent likewise local, and if its development in a state of perfect health is possible, it must be confessed that such cases are proportionally rare

and that the greatest number depend upon local or general disturbances of the economy of greater or lesser gravity, so that the majority of the problems of the etiology of caries rest in reality upon exact notions of general or special pathology. Finally, our experiments seem to have clearly established, without the necessity of further insistance, the exclusive action or the adjuvant influence of direct agents of alteration coming from without.

## CHAPTER III.

### PROGRESS, SYMPTOMATOLOGY, COMPLICATIONS.

In the study of the progress, the symptoms, and the signs of dental caries, adhering to the method adopted throughout the course of this treatise, we shall consider the phenomena of this order in the three successive degrees of the malady, and in their relations to the diverse forms presented by the alteration.

### § 1. *First Period.*

Caries begins upon a tooth whose crown is intact, as a minute whitish point, superficial, opaque, perfectly indolent, whether spontaneously or to the touch of an instrument. This minute white spot results, as we have already described, from the separation, at first over a limited extent, of the enamel prisms previously exactly contiguous, and is accompanied by a destruction of even the substance of these prisms, which may be reduced by scraping to a fine and chalky powder, in which, under the microscope, we still recognize some deformed débris of the primitive elements. The first appearance of caries consequently takes place at the most superficial portion of the enamel layer, progressing from this point toward the centre of the tooth, and following pretty constantly the direction of an imaginary line extending from the

point originally attacked even to the centre of the pulp cavity, a direction no other than that of the canalicules themselves. This beginning is constant, and the malady never has another origin; therefore *internal caries* does not exist. Those cases have been regarded as internal caries in which a narrow and sometimes hidden opening in an interstice, or at some other point of difficult access, has opened into an excavation of greater or lesser size, which thus might long remain unnoticed and which some fortuitous circumstance, a shock, at once discloses by breaking away the thinned wall of the cavity. It has been also asserted, in support of this opinion, that the wisdom teeth at their eruption are often carious (Hunter, M. Oudet). This assertion rests upon inexact observation. The wisdom tooth, whose eruption is, as is well known, often retarded and disturbed by various complications, is for a period, sometimes of long duration, covered with a layer of the gingival membrane, perforated with an opening insufficient to give passage to the crown, or reduced to a condition of shreds which remain attached to its surface. Now these shreds, quite liable to become inflamed, may give rise to the production of mucus, pus, and other inflammatory products. They are, moreover, susceptible of concealing as in a pocket in contact with the organ alimentary fragments, which become a veritable centre of fermentation and thus a cause of caries. The tooth, at last accomplishing its eruption, may show on its exterior caries, even of great extent, the careless examination of which has referred its origin back to an epoch anterior to the eruption.

Another argument, more serious in appearance, rests upon cases of teeth found in ovarian cysts, in fœtal inclusions, in various heterotopic productions, in which ca-

ries has been found to exist.[1] We have personally observed a number of examples of this kind, and have easily seen that the pretended caries was nothing but the resorption, more or less advanced, of the teeth fixed to the walls of the cyst, resorptions which are in all points analogous to the phenomenon which takes place in spontaneous and progressive wasting of the roots of the temporary teeth. In some of these accidental cavities the teeth showed this state of resorption so far advanced that they were reduced to minute fragments, and thus could readily be taken *a priori* for alterations of the nature of caries.

This malady is then never met with in such circumstances, although it might be admitted that teeth plunged in a liquid would be likely to undergo various chemical alterations. But the liquid of the cyst is alkaline and seems incapable under any circumstances of taking on an acid reaction. Other alterations simulating caries are also found on teeth contained in these heterotopic productions; such as depressions, interruptions, or losses of substance of the enamel dependent upon erosion, and which are so much the more notable in that these organs under such morbid conditions are always marked with various anomalies.

The alteration of the layer of enamel once begun at the surface, a minute depression is formed by the loss of the dissociated elements of the tissues, and, the infiltration proceeding in the interstices and along the contiguous faces of the prisms, caries appears in the form of a cylindroid cavity, soon measuring its depth by the length

[1] See the remarkable work of Lebert on *Les Kystes Dermoids* and *L'Hétérotopie Plastique* in general, in *Comptes Rendus* and *Mémoires de la Société de Biologie*, 1852, vol. iv., p. 203.

of the prisms themselves at the point of the disease, and penetrating even to the outermost portion of the substance of the ivory. During the greater part of this period, no sensation, no pain has warned the patient of the existence of the malady, the enamel being absolutely without sensibility. Direct exploration would indeed discover the presence of the primitive depression, but if the altered point is removed from sight in a space between the teeth, nothing can at first reveal it.

This initial phase of the malady is at times entirely wanting, and we have seen that certain teeth, whose evolution has been more or less arrested or disturbed, present at the surfaces of their crowns depressions, crevices, holes of various forms penetrating the enamel to a variable depth and frequently even reaching the ivory. In these latter cases, caries, when originating in points so predisposed, begins at once at the second period.

Arrived at the limit of the depth of the enamel, the alteration meets at the outermost part of the ivory that gray layer, whose constitution should not be forgotten, crossed by a series of minute cavities, which we have designated the *anastomotic plexus* of the dentinal canalicules.

At this moment two peculiarities present themselves: if the caries has advanced slowly by reason of the lack of energy or of duration of the altering cause, it finds the ivory, as it were, prepared for resistance by the augmentation of the density of its substance, and meets the base of the transparent and compact cone whose anatomic characteristics we have previously examined; the dentinal canalicules are obliterated wholly or in part by deposits of secondary dentine; the anastomotic plexus, which offers itself so readily to invasion, is filled up by the same process, and the uniform and homogeneous substance op-

poses its density and its resistance thus accrued to the progress of the malady. Now if the altering cause happens at this moment to diminish or suspend its action, the caries is arrested definitively or temporarily, up to a new advent of a destructive agent. Such cases are frequently met in practice, where we find caries which ordinarily shows itself as a black or brown spot, through the penetration of coloring matters, and in which the excavator introduced soon meets with a hard and resistant surface. Caries takes on these characteristics when it occurs, for example, on a portion of a tooth which, after having been in contact with the alteration of a neighbor, has become subsequently isolated by the cure or the extraction of the latter, and thus removed from the chances of further alteration. This slow form of caries susceptible of momentary or permanent suspension is accompanied by a consequent peculiarity, namely, its frequent absolute insensibility. We remark thus that, either spontaneously or under external influences, such as the contact of the probe, etc., the cavity, even at the level of the superficial layer of ivory is absolutely inert, a fact the more surprising at first thought, in that this layer normally possesses an excessive sensibility; this is due to the circumstance that the same processes which have brought about the obliteration of the canalicules and of their anastomoses have rendered the mass of the tissue absolutely impermeable, and in consequence inapt for the transmission of external impressions. Thus the instrument which explores the depths of a small cavity of this kind is enabled to recognize that the tissue possesses a considerable resistance and hardness.

As for the mechanism of these vital modifications which produce the obliteration of the canalicules and of

their terminal enlargements, as we have already said, it is the result of the irritation excited at the periphery of the tooth by the very change it has undergone. This irritation transmitted to the pulp provokes on its part a functional super-excitation, and the materials it elaborates under this influence, carried into the canalicules by the liquid which fills them, deposit themselves along their channels, producing thus, by this centrifugal transportation of secondary dentine, the metamorphosis of the ivory into a homogeneous and uniform mass. The slow progress of the caries at this first period, with the various phenomena just described, is far from being constant, and the malady may take a rapid form which entirely changes its characteristics.

When, following upon a cause of alteration, active or energetic, the caries has in a little time pierced the whole thickness of the enamel coating, indicated by the greater friability of the tissue and the whitish or yellowish coloration of the parts, the cavity presents a sensibility, often very acute, to impressions from the outside, such as rapid transitions in the temperature of the mouth and the contact of instruments. This depends upon the fact that the caries, coming swiftly upon the superficial portion of the ivory, finds this tissue unprepared, so to speak, for the contest, having no trace of any cone of resistance to oppose to the malady, or provided only with a cone imperfect and incomplete. The caries then finds this layer of anastomotic cavities excessively sensitive, because no production of secondary dentine has penetrated and filled them. This sensibility, corresponding to the end of the first period, or the beginning of the second, is really the first painful symptom to which the malady in its progress towards the centre of the organ gives rise.

It is more likely to occur at the neck of the tooth by reason of the slight thickness of the enamel to be traversed by the alteration, and here it sometimes becomes so intense that instead of occurring solely upon direct provocation, it comes on spontaneously and permanently with an acuteness at times comparable to that resulting from the exposure of the pulp itself, and direct exploration there finds a soft and depressible bottom, contrasting strongly with the hardness and resistance of the preceding form.

The two extreme conditions of slow and dry caries, on the one hand, and soft and rapid on the other, are found at every period of the alteration ; and just as indolence is the habitual character of the former, so is the latter always sensitive and painful. These distinctions explain how certain kinds of caries at their beginning and while insignificant in extent are extremely painful, whilst others cause not the least sensation and increase without the patient's being conscious of them.

### § 2. *Second Period.*

The second period begins at the moment at which the caries has begun to attack the ivory. In this we shall find the same variations as in the preceding period according as the alteration is slow or rapid, that is to say, as the efficient cause is weak or powerful. If the malady progresses rapidly it extends its ravages in every direction, and as it spares comparatively the enamel layer at the sides of the opening by reason of the greater resistance of this tissue, it excavates a cavity, sometimes of considerable depth, whose orifice remains narrow. This very frequent disposition is eminently favorable to the progress of the malady, the cavity so formed becoming

a new receptacle for all the chemical actions of which the mouth is the seat.

The direction usually taken by the caries in the interior of the ivory is that of the radius of the crown; nevertheless it may take many different directions. Thus it is often seen to be developed in width beneath the enamel layer, which, gradually becoming detached, discovers an extensive caries, but of slight depth. This is the form to which Duval gave the name of denuding (*écorçante*) caries; at other times there is a narrow but deep cleft, as is observed in the intervals of the tubercles of the molars and at the neck. But all these varieties, infinite in the appearance and disposition of the decay, have but a secondary importance.

The rapid form at the second period is accompanied by a considerable softening of the ivory, of greater or less extent, rapidly arriving at the neighborhood of the pulp cavity. This organ, finding itself then in contact with the surface of ivory already altered, becomes disturbed in its vitality and its functions, without as yet taking on that symptom of true inflammation which we shall notice in the third period. These perturbations sometimes bring on the suspension of the normal and permanent production of dentine, sometimes excite isolated points of super-excitation or irritation, which give rise to those minute nodules or granules of phosphate of lime, or to those irregular lamellæ of ivory whose composition we have previously examined.

The painful symptoms proper to this degree of the malady are usually proportionate to the extent of the alteration. Nevertheless, it is worthy of remark that some caries of the second period is less painful than others of the preceding period, caused, as we have already

observed, by the difference of sensibility in the layers of ivory affected. The pains, nevertheless, are generally *excited* and not *spontaneous*, that is to say, they come on only under the influence of foreign contact, the passage of a liquid at a temperature varying from that of the mouth, a sweet or acid substance, etc. The sensation at such times, although occasionally very acute, is usually fleeting and disappears rapidly after the removal of the exciting cause. It is also very variable in its intensity, according as the position on the crown of the tooth occupied by the caries is more or less exposed. Thus, a cavity situated in a dental interstice may remain absolutely indolent up to the very exposure of the pulp, whilst if on the triturating face of a molar it will be early exposed to a crowd of painful excitations.

Certain symptoms also belong to this second period in its rapid form. An exploring instrument passed into the cavity finds a considerable softening of the wall, and may remove, in the shape of laminæ of a cartilaginous appearance, complete layers of ivory uniformly softened. Below the first most altered layer the instrument encounters others in regular order which are more and more dense in proportion as they are nearer the point where the ivory continues sound. This exploration is not made without pain, but the sensation varies according to the point encountered by the probe; thus, it is generally very acute near the most superficial layer of the dentine upon the sides of the external orifice, but is very much less and at times absent in the deeper regions, becoming again acute as it nears the vicinage of the pulp. This circumstance shows how careful should be the examination of a caries, especially in the deeper parts, and should put us on guard against any imprudent manœuvre which may suddenly

uncover the central pulp, and at once change a case of caries of the second period to one of the third.

In the slow form, the caries, reaching the base of the cone of secondary dentine and continuing its destructive work, takes there a direction which, in place of following regularly the radius of the tooth, spreads by reason of the resistance of this tissue upon the sides of the original opening. These circumstances give rise to a variety of peculiar appearances. The color is ordinarily brown or black; the surface, endowed with an indolence and insensibility often absolute, offers at the same time a much greater density, and with difficulty suffers itself to be removed by the file. These peculiarities, which are found even in cavities of large dimensions, are due to the phenomena of condensing dentification of the canalicules and the retreat of the pulp cavity. It is thus that we may explain how some cases of caries have never been painful, even when they have occasioned the total loss of a tooth. It is because the pulp, retreating step by step as the caries progresses, never permits itself to become exposed, although the malady, overcoming the resistance of the organ, at last invades it in its totality. Caries of a slow progress has at times a very considerable duration, and, whilst the rapid form may destroy a tooth in the space of some months or even weeks, the former attains the same result often not till after one, ten, or even twenty years. It is this form especially whose phenomena after having gone on a certain time are susceptible of suspension, a real arrest giving rise to the production of what is called *dry caries.*

When during the course of caries, and after it has already destroyed a certain thickness of the crown, there occurs any circumstance that suspends the influence of

the destructive agent, or if the malady in its progress reaches a layer of dentine become extremely compact and resistant, in consequence of the mechanism we have examined, the alteration arrests its march and remains stationary. The case then ordinarily presents itself, as we have seen, as a cavity of slight depth, or even as a plain surface more or less irregular, at times smooth and polished, and of a brown or black color. The hardness of the tissue explored with a proper instrument is extreme, and suffers it to be removed only with the greatest difficulty. It gives rise to no pain, either spontaneous or when disturbed; it is for the most part insensible to every influence, a fact explained by this very density of the dentine. Nevertheless if we scrape away with a file the external layer of a dry caries, we may find beneath layers having a certain sensibility. This fact, which necessarily indicates the persistence in the centre of the organ of a fragment of the pulp, depends upon this, that the instrument reaches some canalicules still permeable and capable of transmitting the impression received.

This suspension of the march of the malady which produces the *dry* caries may be definitive and bring with it the spontaneous and radical cure of a tooth. But this mode of termination is not absolute, and in some cases the alteration, after a more or less prolonged suspension, may begin its progress again, and there may be seen upon a point of dry caries a caries of the soft kind. This fact, ordinarily the result of a return of the alterant cause to activity, occasions the production of a new cavity, which may attack the whole remaining mass of the crown. This is the humid form grafted upon the dry, but with this peculiarity, that, produced upon a compact and resistant soil, it generally advances slowly, and may even again be

arrested in its progress, giving rise to a return of the cure; finally, after several alternate arrests and advances, the caries reaches the boundary of the pulp cavity, beginning the third period of the malady.

### § 3. *Third Period.*

The third period of caries begins with the very moment when the cavity of the pulp has been penetrated. This phase of the malady pertains as well to the slow as to the rapid form of caries, with a difference nevertheless in the tardy or hastened epoch of penetration. The moment of the invasion by caries of the centre of the tooth varies with the age of the subjects, for we know that the volume of the pulp, considerable in the infant, diminishes progressively throughout life, and ends in the aged by disappearing. It results from this that, all conditions being otherwise equal, caries will uncover the centre of a tooth far earlier in young subjects than in others. Thus deep and painful caries is relatively rarer in old age.

However this may be, this last period of alteration differs, as do the others, in its peculiar physiognomy, according as it corresponds to one or the other of the two types which we have followed in this memoir. We should therefore regard successively the slow form and the rapid form.

When a caries of the slow kind, at its third period, passes the boundary of the pulp cavity, it may meet this organ with its ordinary volume and constitution; but this is rare, and, most frequently, by reason of this very slowness of progression, the organ has notably diminished in volume; it is cut up into shreds, or in part transformed into dentine, and the cavity that contained it is become creviced, uneven, divided up by the irregular deposits

with which it is encumbered. The alteration, having thus come into contact with the remains of the pulp, at once puts an end to every symptom of further dentification on their part, smites them with gangrene, and at last, making its way into the hollows left free by them, occupies the very centre of the tooth and extends its ravages on every side, destroying the partitions and every production whatsoever of secondary dentine, and even the subjacent regular layers of ivory. In general, however, this phenomenon of partitioning and of the production of massive ivory may be so marked that the caries, at this moment of penetration, may find a barrier able to perceptibly retard its advance, until, by its increasing energy, it at last destroys this new hindrance and pursues the last fragments of the pulp even to their entire dissipation.

If the caries encounters in the centre of the tooth a complete formation of dentine consecutive upon the total atrophy of the pulp, it should, in order to advance beyond, be endowed with a certain activity necessarily superior to the resistance and density of the tissue of new formation; for without this condition, it remains smitten with inertia, and pauses to pass to the state of dry caries. Finally, in certain cases, the caries perforating the wall of the pulp finds this cavity completely free in every part, without a trace either of the organ itself or of any products of secondary dentine whatsoever. This peculiarity is due to the fact that the pulp has been smitten with mortification or resorption during the course of the second period, without having been able to put forth any effort of resistance. The malady, thus lodged freely in a spacious cavity, generally acquires greater energy, and may even become rapid, however slow at first.

The symptoms of this condition, belonging, when there remains any portion of the pulp, to the exposure of this organ, will be described farther on when we come to the rapid form. Nevertheless, we should say here that the various accidents are in general of little intensity by reason of the reduction in volume the organ has undergone, and of the disturbances of greater or less degree in its vitality which result therefrom. The exploration of the cavity by means of the probe reveals, beyond the canal which gives passage to the instrument, a region full of crevices, irregular, into which the point of the finest broach penetrates with difficulty, meeting in the midst of masses of dentine fragments of pulp in a more or less altered state. From these phenomena of resistance alternating with frequent returns of attack upon the centre of the tooth, this period is above all others characterized by intermissions of painful crises and of calm, corresponding precisely to the alternations of perforation and reparation of the walls of secondary dentine, so that the pulp, now protected, now exposed, passes successively from an inflammatory phase to a quiet one, until it has entirely disappeared. Finally, in some circumstances of this last period, the malady presents a character of absolute indolence and insensibility, arising sometimes from the progressive and complete retraction of the pulp, sometimes from the total dentification of the organ. If the caries at this third period takes the rapid form, it presents special peculiarities, and as it is much more frequent than the dry form, we should pause longer upon its characteristics. At the moment of the penetration of the cavity of the pulp and of the denudation of this organ, the first phenomenon that occurs is its inflammation. This, the result of the influence of the air and of external

agents, is limited at first to the single denuded point, and afterwards extends from point to point, to the totality of the tissue. It immediately strikes this organ in its functional aptitudes and its vitality, and renders it thenceforward unable to oppose the least resistance to the malady. The inflammation, which the rapidity of the onslaught suffers neither to be alleviated nor cured, ends ordinarily and rapidly either in dissolution of the tissue or its gangrene. The central cavity of the tooth, deprived thus of the organ it contained, permits itself to be freely invaded by the caries, which, left henceforward to itself, spreads in every direction, softening and destroying little by little the whole of the crown. Such is in short the mechanism of the progress of caries at its third period, when it affects this rapid form.

To this body of facts correspond special symptoms and particular signs. If the inflammation developed in the pulp after its exposure is superficial and slight, the pain is usually intermittent, returning by access, sometimes regular, or renewed by some exciting circumstance, the contact of the air, a cold liquid, a shock, the pressure of a particle of food, the vacuum made in the mouth by suction, etc. This pain, primitively limited to the dental region, is often at first rather vague, and the patient but rarely distinguishes the exact spot; sometimes accusing a neighboring tooth, or the corresponding tooth of the opposite jaw, peculiarities due to the neuralgic localizations upon the more or less distant points of the same nervous trunk or its secondary ramifications. These pains are not always limited to the teeth and jaws, but appear at a point quite distant from the seat of the disease, and may be found, in a general way, upon some ramification of the sensory nervous system of the face on the corre-

sponding side. It is thus, for example, that decay of a lower molar sometimes causes pain at the point of emergence of the dental nerve from the mental foramen, or on some branch in the neighborhood, sometimes on the nervous filaments of the cervical or cranial region. On the other hand the caries of an upper tooth produces pain at the emergence from the sub-orbital foramen, or on one of the cutaneous branches of the temple, of the eyelids, of the cheek, and even of the scalp; the painful points may multiply to such a degree as to constitute a veritable hemi-cranial neuralgia.

Be the case as it may as regards these fixed or wandering pains, — to which we shall again recur when we come to the matter of diagnosis, — they always belong to the inflammatory condition of the dental pulp. If this condition is limited to a superficial irritation it can produce only various neuralgic pains, either near or remote; if the inflammation is general the pain changes its nature, and, remaining local, with or without nervous irradiations, becomes continuous, lancinating, with transient exacerbations, and may go on to such an intensity that it is considered one of the most acute it is possible to experience. These crises, resulting from the general inflammation of the dental pulp, owe a new vehemence to a peculiar phenomenon, namely, its *strangulation* in the cavity that contains it. This may be observed even by direct exploration. If we introduce to the bottom of the caries, and during a crisis, an exploring instrument, we shall speedily find, presenting itself immediately at the opening of the passage, the swollen pulp, whose contact is excessively painful; if the same thing is repeated after the cessation of the paroxysm, the instrument may have to penetrate to a considerable depth before encountering the organ, which has fallen back to its normal volume.

When the third period of the caries is already advanced and the wall of the pulp cavity has itself undergone a partial destruction, the organ, after having experienced a series of inflammatory crises which have caused the loss of a portion of its volume, finds itself reduced to the condition of shreds that gradually disappear in their turn, and the cavity, completely emptied, is given over passively to destruction. The crown, thus penetrated to its very centre, is not slow to disappear entirely, leaving in the jaw nothing but the roots, held by their alveoli. To the disappearance of the crown under the invasion of caries and to the mortification of the pulp succeeds a series of destructive acts, purely passive, which have their seat in the roots themselves. The softening pursues its ravaging course through their very centre, and causes them to undergo an alteration of the same nature as in the other portions of the organ. Having reached this extreme phase, the caries may nevertheless become arrested and pause again in its advance, no longer by the intervention of the vital forces of the tooth, but through the momentary or definitive removal of the productive cause. It is thus that numerous fragments or roots of teeth destroyed by caries may remain in the mouth without causing any disturbance, and even carry on some part of the process of mastication. At other times the persistence of the altering cause carries the malady quite to the ends of these roots even in the interior of their alveoli, and then occur various phenomena whose consideration should arrest us for an instant. The destruction of the pulp, accomplished in the third period of the caries, is soon followed by that of its prolongations in the dental canals, and the course of these open canals is then followed by the malady in its invasion of the roots. The organ,

henceforward deprived of its vital and functional centre, would no longer have reason for remaining in the economy, were it not that the periosteum, the alveolo-dental membrane, by its connection with the cement and through its intermediation, communicates still to the ivory a certain rudimentary nutritive movement. But if the caries interferes with the integrity of the periosteum itself, this then, reacting, becomes the seat of inflammation, at first acute, partial, and local, then consecutively general and chronic with passing returns to the acute condition, production of sub-periosteal abscess, of purulent cysts, of fungous growths, etc.

This is not the place to trace the history of periostitis and its various forms. We have simply to consider the appearance of these phenomena at the ultimate period of the caries, as the mode in which the elimination of the last mortified débris of the tooth is conducted. We will nevertheless remark that these inflammatory accidents, which often affect in a serious manner the neighboring parts of the face and the general health, are not exclusively caused by the fragments or the roots of the carious teeth: they occur frequently in the course of the third period and as complications at the times which immediately follow the first lesions of the pulp.

However this may be, the caries cannot in general and of itself alone effect the total disappearance of a tooth, and when its roots in their turn undergo the alteration which has destroyed the crown, they experience, when the softening reaches the deepest portions, a sort of lifting or spontaneous luxation consequent upon the repeated inflammations of the periosteum, and are, in fine, thus detached and driven out of the economy.

## Complications.

The *complications* that occur in the course of caries are extremely numerous, and their history will comprise a great part of the pathology of dental caries. We have already remarked some of them while studying its progress and symptomatology; others will be touched upon in speaking of the treatment. We shall confine ourselves here to a résumé of the principal ones.

In the first period, almost always indolent, complications are ordinarily wanting, except perhaps gingivitis in connection with caries at the neck of the tooth, a local affection which terminates as soon as the caries is cured.

In the second period, besides some local accidents of the same kind, we observe divers phenomena of the vicinage, such as neuralgic points more or less distant from the seat of alteration, upon which we have enlarged sufficiently in this chapter.

In the course of the third period the complications are more numerous and important. They may be divided into local accidents, accidents of vicinage, and general accidents.

Among the local complications the most frequent of all is alveolo-dental periostitis, developed, as we have said, by propagation of the pulp inflammation in the canals of the roots to their apices. This periostitis, sometimes simple and clearly inflammatory, may itself be complicated with various other lesions, such as abscess, purulent cysts, fungous growths, etc.

These different forms of periosteal affections may become in their turn the points of departure of other disorders of vicinage: phlegmons of the gum or of the cheek, abscess opening in the mouth or outside upon the skin,

consecutive fistulas, and more or less extended affections of the alveolar border or of the jaws.

Other phenomena of an organic nature sometimes accompany caries, having for their seat the periosteum; such are the various tumors, and more particularly the polypi, which we have already spoken of in our *Pathologic Anatomy*. These small pedicled products, occupying by their mass the whole cavity of the caries, in general are not serious, and their excision followed by cauterization of the pedicle enables the regular treatment of caries to be proceeded with.

These are not the sole productions which may be encountered in caries, and we have previously spoken of others having their seat sometimes in the gum, various growths whose excision is easy, sometimes in the pulp itself.

We will not insist further in this place upon the various lesions of the periosteum or of the pulp which complicate the caries, their history belonging in reality to another work.[1] Among the local troubles of the mouth we should remark the suppression of the functional acts on the side corresponding to the affected tooth. In fact, under the influence of the annoyance or of the pain occasioned by caries, the patient instinctively uses the opposite side for the functions of mastication. The first inconvenience resulting from this is the accumulation of hardened mucus, of tartar and other deposits of foreign matters upon the whole inactive region. This complication soon brings on others more serious; the gingivitis, at first local, soon becomes generalized. Moreover, the teeth, deprived thus of their use, become, so to speak, soft and sensible to pressure, so that, even when we suc-

[1] See our *Traité d'Odontologie*.

ceed in suppressing the morbid cause, they find difficulty in resuming their habitual office.

The various accidents of vicinage we have to note are, first, those arising from the nervous system, which are especially numerous and acute at this last period. We already know of them, and we shall recur to them more usefully when treating of the diagnosis.

We ought to mention a symptom sometimes occurring, namely, *salivation*. It may be so abundant as to constitute a new cause of disturbance by provoking an incessant spitting. This fact is easily explained by the consideration that the nervous system of the salivary glands is under the control of the fifth pair.

There is another complication upon which we should dwell as not unfrequent and of sometimes difficult interpretation; we refer to the lesions, sores, ulcerations, tumors of the tongue and of the cheeks, caused oftentimes by the sharp or projecting corners of carious teeth.

It is, in fact, quite often observed that the tongue or the cheek, constantly encountering in its movements the sharp ridge formed by the border of a caries, becomes irritated and ulcerated upon the correspondent point. The ulceration spreads, becomes indurated at its base, and finally represents a veritable tumor. This lesion appears almost always upon one of the sides of the tongue, caused by caries of the inferior molars. Errors of diagnosis are often made under circumstances of this nature, their relation to the accidental cause not being perceived, and they are thought to be essential affections, inflammatory or organic, of the tongue itself. We would warn against so frequent an error, and recommend, in cases of lesion of the tongue on the parts adjacent to the teeth, their attentive examination.

Another kind of complications has regard to certain lesions of the organs of sense, otalgia, for instance, partial or total deafness supervening sometimes under the influence of dental caries. Disturbances of the vision, or of the functions of the eye, are likewise observed; other phenomena of the same nature are caused in the senses of smell and taste by caries of the teeth in relation with nervous ramifications to the sensorial regions. The most frequent accidents observed by us have been otalgia and deafness, depending pretty constantly on the decay of a lower molar, and more especially of the wisdom tooth. Certain cases of this sort, whose real cause was not suspected and on which the series of treatments directed to the ear had no effect, have yielded completely to the cure or extraction of the diseased tooth. We have collected several observations of this nature which want of space prevents our publishing here, but which will find their place in a subsequent treatise. The same is the case with disorders of the vision depending upon caries of the upper teeth, the canines and bicuspids, for example. We observe at such times running at the eyes, spasmodic contraction of the orbiculares, or of the muscles of the globe, strabismus, and at times even a weakening of the vision, without doubt through reflex action upon the nervous system of the iris or of the retina.[1] Of the accidents produced in the sense of smell, we may instance certain lesions of the maxillary sinus, occurring under the influence of the decay either of the second bicuspid or of the first or second molar. These are inflammations, abscesses, mucous or other cysts, as so well described by M.

[1] See Hancock, *Amaurosis and various Affections of the Apparatus of Vision Symptomatic of Dental Disorders; The Lancet*, January, 1859, and *Arch. Gén. de Médecine*, 1859, p. 224.

Giraldès.[1] We should say, nevertheless, that they are all caused much less by the caries itself of the teeth bordering upon this cavity, than by complications of the dental periosteum, such as abscesses opening into the antrum. These facts, therefore, pertain especially to the history of periostitis.

The complications occurring in the general condition under the influence of caries are due either to the intensity of the exacerbations of pain, or to the various lesions of the vicinage occasioned by the dental malady. We may observe at such times disorders of the nervous system, or febrile conditions. It is thus that caries has been able to occasion, for example, attacks of eclampsia, to excite epileptic attacks in persons otherwise predisposed to them, delirium, etc. As for the febrile conditions, they may occur during the crises of pain, which then bring on a veritable access of fever with initial chill and divers other phenomena. We do not intend to insist at length upon these particulars, which moreover are very rare, the caries being, in fact, a peculiar local affection bringing on general complications only when multiplied or generalized, or when it has itself been caused by other lesions then consecutively reacting upon the whole of the economy. Such are most commonly periostitis and its various forms, phlegmasiæ of the mouth or of neighboring regions, which bring about disturbances of greater or less gravity, whose description we cannot trace farther without exceeding the limits of the present work.

[1] *Des Kystes Muqueux du Sinus Maxillaire,* 1860.

## CHAPTER IV.

### NOSOLOGY AND DIAGNOSIS.

If we consult, on the subject of dental caries, the majority of the works which have been published in France, articles in dictionaries, monographs, etc., we perceive that the greatest uncertainty still exists as to the characteristics, the causes, and, more than all, the nature of this malady. Most authors, confining themselves to the opinions of Duval, at the beginning of this century, allow seven kinds of caries. Duval asserted that each kind, corresponding to the particular affection that gave it birth, constitutes in some sort a different malady.

The seven caries of Duval are the following: [1] —

*First kind: Calcareous Caries.* Characterized by a slight circular depression near the gum, possessing great sensibility, and with opacity of the enamel, which has become opaque and friable.

*Second kind: Denuding Caries.* A yellow spot on the enamel, which is very friable and at times coming away from the whole surface of the tooth; the ivory is yellow or brown, soft, and little sensible.

*Third kind: Perforating Caries.* A spot on the enamel, more or less dark, degenerating finally into a cavity with yellow walls, sensible to cold, and penetrated by a sort of fetid humidity.

[1] See *Dictionnaire*, in 60 volumes, 1814, vol. viii., p. 348.

*Fourth kind: Black Caries.* A black spot with periphery of the same color, permitting the enamel to be seen through it, which at this point appears of a bluish tint. The walls of the cavity are dry, friable, black, with neither odor nor sensibility: progress rapid.

*Fifth kind: Stationary Caries.* Spot and cavity black, the same sign of invasion as in the foregoing; causing Duval to say that it might be a variety. It is insensible and inodorous; but it differs from the former in that its walls instead of being friable are as hard as in the sound condition.

*Sixth kind: Polished Caries (caries curata).* Peculiar to the molars. Characterized, according to Duval, by a depression of a black or brown color, insensible, hard, and polished as by friction, whence the name of *caries simulating wear*, which has also been given to it.

*Seventh kind: Diruptive Caries.* It shows itself on the roots of the teeth near the crown, at the neck; it is characterized by softening and the formation of a yellow cavity, crossing the tooth transversely in such a way as to effect the horizontal section of the crown.

If we examine attentively these seven definitions of Duval, we readily perceive that some of them are almost completely confounded: thus, the first is, in our opinion, nothing but the common beginning of every case of caries; whilst the second and third are two modes of different direction, according to the nature of the agent of alteration; the fourth is the black caries, simple matter of peculiar coloration, and in which we, with Tomes, but contrary to Duval, perceive a slow progress; the fifth and sixth are represented in our doctrine by the *dry caries;* and in fine, the seventh is no other than the caries of the neck of the tooth, or serpiginous caries.

The opinion of Duval does not, therefore, seem tenable, and if a last argument were necessary, we might answer that almost all the characteristics, almost all the variations have been found in caries produced artificially either in the mouth or in our laboratory experiments. It remains then demonstrated that the pretended different lesions are nothing but forms of the same malady. Caries is one.

By the side of this doctrine of Duval we should place another, already mentioned, which is still defended by M. Oudet. According to this theory there are two kinds of dental alterations, erroneously confounded, according to him, under the name of dental caries: *first*, purely *chemical alterations* attacking directly the teeth from the surface to the centre; *second*, a peculiar organic lesion of the ivory and enamel, proceeding from the interior to the exterior, and which is caries proper.

We have already objected to this distinction, which besides has been adopted by no author, and seems to us to rest upon no exact observation.

There exists in reality no fact of internal caries, the cavity closed in every part, originating spontaneously, spreading in the interior of the ivory, and bringing on the destruction of the organ. We oppose the most formal negation to this pure hypothesis of internal caries, and challenge any one to produce a single example. Every circumstance, moreover, of seat, of form, of direction, even to the very mechanism of the spontaneous or artificial cure, is in entire opposition to this doctrine.

These remarks also sustain all the results of this examination, permitting us to regard dental caries in a new light, and to give a precise determination of its nature, points summed up in our definition heretofore given, and

in the conclusions which will be found at the end of this book.

Our doctrine nevertheless is not taught by us alone; it has been anticipated and hinted at by several authors, Regnart, Tomes, Harris, etc. We have only developed and confirmed it by subjecting it to the tests of observation and experiment.

From these considerations this consequence results immediately, that the name of caries is eminently improper to designate and represent an affection of external origin and of a chemical nature. Nevertheless we have no intention of changing it and proposing a new name for the designation of this malady. This conventional term, *caries*, consecrated by usage and tradition, appears to us preferable to any attempt at neology.

*Diagnosis.* — Dental caries being an alteration of external origin causing the formation of a cavity with an always permeable orifice, it would seem that its diagnosis would always be easy; it is not so, and in very many cases the determination of the presence, the situation, and the extent of the malady presents great difficulties.

Whilst the lesion remains relatively indolent, that is to say, during the first and a portion of the second period, the patient perhaps may never become aware of it, even by accident, and may remain wholly ignorant of its existence. Nevertheless the minute exploration of the mouth permits its discovery by certain peculiar signs.

In fact, when the observer remarks upon a point of difficult access, as, for example, the interstice between two teeth, or the posterior face of a molar, minute white or bluish spots, which examination with a mirror allows to

be more clearly seen, we may decide that there is caries. The demonstration of its existence may be subsequently obtained either by forcing an artificial separation of the contiguous teeth by means of strips of caoutchouc, or a separating file, or by cutting away the thin wall, where the case is one of greater probability, by means of a proper instrument. This last operation is indeed often useless, for the exploring instrument, by its simple passage over the affected portion, suffices, with slight pressure, to break through and thus penetrate the caries, producing a sensation of pain more or less acute. In the more advanced period of the malady, when the pains have already begun spontaneously under their different forms, the existence of caries, otherwise ascertainable with difficulty on account of its position, may be very obscure. Thus, it sometimes happens that a cavity, either of the end of the second period, or penetrating, remains still completely hidden from the eye in an interstice or at some other point difficult to reach, and that, moreover, the pains, instead of locating the very seat of the alteration, radiate vaguely to various parts of the face and jaws, or fix themselves sometimes upon an entirely sound tooth in its neighborhood or in the opposite jaw, sometimes upon some nervous ramification. The patients may then complain of a sensation at a point which has no lesion, or of a facial or cranial neuralgia, partial or general. It is then necessary to state here the precise physiognomy of these various sensations in their relations with the seat of the malady.

Thus it constantly happens that a painful caries of an upper tooth, and more particularly the molars, gives rise to neuralgic points according as the branches are supra or sub-orbital, or temporal, superficial, and cutaneous;

further, that the pain may completely wander from its origin and fix itself upon a tooth of the lower jaw, generally the homologous tooth, and there locate itself so clearly that the patient may mistake entirely, carrying along with him in his belief a careless observer. This phenomenon, due either to reflex action or to the reciprocal anastomoses of the superior and inferior dental branches, is very frequent when the sensation has not reached sufficient intensity to become definitely located. The same aberrations may be noticed in the lower teeth. Thus, the caries of a molar or wisdom tooth will often give rise to a fixed pain at the place of the first bicuspid or canine, that is to say, at the point of emergence of the mental branches, and at the same time we may find that pressure with the finger at this point produces a modification of the pain, ordinarily quieting it. Reciprocally, the disease of a canine or incisor may produce pain in one of the molars. In other circumstances the most distant points become the seats of the pain ; thus, the cutaneous branches, cervical or cranial, and more particularly the auricular and temporal fibres, are almost constantly affected in the case of caries of the last molars, and become the seat of that pain which so often seizes the superficial integuments behind the ear, and in the mastoid region. As for the painful points of the regions of the neck or of the head, and even of the shoulder, under the influence of the same causes, they may occupy one of the superficial cervical or cranial branches of the fifth pair and of its anastomoses with the cutaneous ramifications of the facial and of the cervical plexus.

The various nervous lesions whose relations with the dental alterations of one or the other jaw we have established may, in certain cases, be produced alone and per-

sist for some time without any special sign calling attention to the mouth. It is then thought to be facial neuralgia, and an attempt is made to effect a cure in this direction without arriving at any result. It is often only after a very prolonged treatment of this kind that the thought occurs to examine the dental system.

This examination, under circumstances so obscure, demands a very careful attention. Thus, after the exploration, by the aid of the probe, of the surface of the teeth, of the interstices in their accessible parts, we should have recourse to the mirror, throwing, if necessary, a jet of artificial or natural light successively upon each tooth. A German physician has even proposed, quite lately, the exploration of the mouth by means of an apparatus, very ingenious but impractical, by which the examination of the dental arches is to be made by lighting them by a jet of electric light.[1] Without having recourse to such complicated processes, we can find other more simple means sufficient for our demonstrations. Thus, the throwing a jet of water of a very low or very high temperature is an excellent method, and when this is done with a syringe or a small hollow ball of caoutchouc upon the teeth of the suspected region, the patient will generally recognize the exact position of the malady by the sudden sensation caused by the liquid.

Another method has also been proposed: it consists of causing an electric current to pass along the whole extent of the dental arches by means of one of the little induction apparatuses so frequently employed nowadays in medicine. By the passage of a current so feeble as not to cause of itself any pain, the carious tooth will become the seat of an acute and clearly localized pain.

[1] Stomatoscope of Dr. Brucke, of Breslau. *Gazette des Hôpitaux*, 1866, pp. 47 and 55.

Other experiments may also be tried in doubtful cases; thus the vertical or horizontal percussion by means of a small ivory hammer, or of the handle of an instrument, upon a series of contiguous teeth, will enable it to be perceived that the sensation, not painful upon the sound teeth, is slightly so upon the affected one, especially if there is at the same time any, even a slight periostitis.

These means, which may be chosen and varied according to varying cases in practice, will, doubtless, coming in aid of direct observation, permit the rigorous and precise determination of every case of caries.

A special diagnostic problem should arrest us an instant. A case of caries being given, we must determine by subjective symptoms, that is to say, by the symptoms experienced by the patient, to what period of the disease it belongs, and consequently to what means of cure the practician must have recourse. This examination is one of marked importance, for in the exploratory manœuvres, often difficult by reason of the position and the direction, both often obscure, of the alteration, we risk, in the absence of premonitory indications, producing various disorders, as, for example, transforming by an imprudent movement a caries of the second period into one of the third, or penetrating caries, by perforating the inner wall, which is more or less softened, or even of tearing and wounding by a quick contact of the instrument the exposed pulp itself, provoking thus a prolonged and painful crisis.

The elements of differential diagnosis of the various phases of caries are as follows: If the patient complains at any point in the mouth of only a very slight and fleeting pain, of simple disturbance or inquietude which the contact of cold air excites, or that of a liquid acid,

or sugar, but which never occurs spontaneously or without appreciable cause, we may conclude, *a priori*, that we have a caries of the first period with exposure of the superficial layer of the ivory. If, moreover, the slight sensation is developed by the passage of the tongue or the brush across the surface of a tooth, we may be prepared for a caries of the neck of the tooth, and direct our observation to that point. If the observed accidents are characterized by a veritable pain of medium intensity, but yet not spontaneous, that is to say, occurring under the same influences as the preceding, impression of the air or of cold liquids, contact with a hard substance in the food, sugar or acid, etc., but presenting this difference, nevertheless, that instead of being eminently transitory and of passing away at once after the removal of the exciting agent, it persists for some time under the form of crisis or access, returning with an identical similarity at each return of the same causes, but, we repeat, not recurring spontaneously, we may conclude that the caries has reached the second period.

Finally, if the sensations just described are accompanied or interrupted by crises or paroxysms of violent pain, of variable duration, but at times lasting for hours or even a whole day or more ; if such crises are of a perfectly spontaneous character, coming on either periodically or at irregular intervals, without excluding, moreover, the paroxysms started by accidental contact with foreign bodies, the acts of suction, etc., we may be satisfied of the presence of caries of the third period, the various phenomena of a spontaneous character being intimately connected with the exposure and inflammation of the dental pulp.

The accidents occasioned by caries, although the most

frequent of those arising from lesions of the teeth and their surroundings, are nevertheless not the only ones which may be observed in the mouth, and we are led to the study of the different dental pains in their relations with the alterations which excite them. This will be the diagnostic résumé of the various pains grouped under the general name of *odontalgia*.

It may be divided into five principal kinds: —

First. *Odontalgia caused by the eruption of the teeth.* It may last during the whole period of infancy and accompany the eruption of every kind of tooth up to the age of twelve, the time of the appearance of the second permanent molar; it appears, nevertheless, more commonly during the first dentition; its character consists of a kind of itching or irritation of the mucous membrane with some signs of swelling of the gum; redness and injection, and a series of general accidents of the most varied kind noticed by the classic authors.

We mention this odontalgia only because it may, with infants, coincide with other pains and especially with those of caries itself, a frequent affection, as is well known, at this age.

Second. *Odontalgia from gingivitis.* This consists in a dull sensation, continuous, rarely limited to an isolated point in the mouth, ordinarily spread over a greater or less extent of the gingival border, not increased, as the foregoing, by any of the influences that provoke the pain of caries, causing difficulty of mastication on the whole side corresponding, and accompanied in all cases by special signs, redness, tumefaction, detachment of the gum, and various other symptoms, according to the nature and form of the malady.

Third. *Odontalgia of alveolo-dental periostitis.* This

is likewise entirely special. We have indicated its character already in the course of this treatise. It is always localized to the affected tooth, intense or dull, according as the affection is acute or chronic, accompanied by shooting pains or throbbing, like all clearly inflammatory pains; it is permanent and continuous, with spasms of exacerbation appearing irregularly and without periodicity. To this state are always added various local accidents easily appreciable: elongation of the sensitive tooth, a slight shock felt by the patient on closing the jaws, pain on percussion and to the pressure of the finger against the gum or the cheek in the direction of the diseased root, etc. In some other complications of periostitis, such as fungous growths, abscesses, tumors, the odontalgia presents certain secondary characteristics, which always resemble the form just described, and are always accompanied by easily appreciable local phenomena.

Fourth. *Odontalgia by true dental neuralgia.* This simulates, in some cases perfectly, the pain of caries; it may present all its characteristics, whether of localization or generalized; it appears also under the form of irregular or periodical crises, and under the same provocations of transition of temperature and other influences. The mistake is then very easy and is often made. The only diagnostic means in cases of this kind consists in the direct exploration of the mouth and the search for caries. In case this examination shows the absence of dental lesion, we may affirm the existence of veritable neuralgia accidentally fixed upon the dental branches, either the principal trunk contained in the sub-orbital or inferior dental canals, or the ramifications thrown off in their intra-maxillary passage, or in the interior of the tooth, or in the pulp itself. This form of neuralgia, which is

changed in no respect by the extraction of one or several teeth, should be treated by the means used for general neuralgias, and especially in our opinion by douches, or hydropathy.

To this veritable dental neuralgia we should add another kind, not infrequent and sometimes endowed with great acuteness. It is observed in the thickness of the alveolar border after extractions of greater or less difficulty. We remark, in fact, under such circumstances, that the point corresponding to the extracted tooth is, even after quite a long time, the seat of pain which presents every characteristic of neuralgia. The examination of the neighboring teeth discovers no caries, and the exploration of the painful region under the hypothesis of a fragment of root remaining in the socket leading to no result, we may conclude the existence of a true *traumatic neuralgia* consecutive upon the disturbance by the preceding operation, and not unlike the neuralgias so common after various chirurgical mutilations, in the stump of an amputation, for instance.

The means of opposing this new kind of odontalgia consists of topical applications or submucous injections, and, in rebellious cases, the complete section of the nerve filaments by deep incisions parallel to the alveolar border and through the whole thickness of the gum even to the osseous surface.

Fifth. Finally, the fifth kind of odontalgia is that of *caries*, whose characteristics we have sufficiently determined, so that, compared with the foregoing, its diagnostic determination may be possible.

Nevertheless there should be added to these considerations some indications proper for the recognition of the nature and the rôle of a caries in the multiplicity of the

pains, more or less general, experienced by a patient when, for example, there are found on the same jaw, of the same side, a not infrequent case, several teeth which may *a priori* be regarded as causes or as participants in the disturbances. There are in fact cases in which are found simultaneously, and even in contact, two affected teeth, the first reduced to the condition of débris or of roots, the second, in appearance intact, but attacked by caries in a position of difficult access. The patient suffering from a badly localized pain accuses at once and often wrongfully the root or the fragment before suspecting the neighboring tooth. The task will then be to specify by means of the symptoms the relative part taken by these two alterations.

Now, in the supposed case, the distinction must rest on the shades even of the symptoms caused by the different degrees of the malady. Every root or every fragment of tooth deprived of pulp is not capable of causing accidents except by the development of inflammatory lesions of the periosteum and the neighboring regions, accompanied by certain signs, redness of the parts, pain upon pressure or disturbance, elongation apparent or real, continued sensation of fullness ; whilst caries occasions, as we have seen, pains excited by various influences, or spontaneous under the form of crises, differences sufficiently marked in most cases to establish the distinction.

A diagnostic determination of the same kind should be made when two or three caries are observed at the same time and of analogous degrees in the same region of pain, the patient being unable to locate his sensations upon any one of them. We should then explore successively all the cavities, in order to establish the period at which each has arrived, and apply the sensations experi-

enced to the degree which habitually excites them. In fine, cases may be met, but very rarely, where two carious and contiguous teeth cause at one time sensations corresponding to their peculiar degree of alteration, whose result produces the feelings experienced by the patient. We should then, by a double exploration, ascertain the part played by each of the two caries, and apply to them separately their appropriate remedies.

## CHAPTER V.

### TREATMENT.

The investigations relating to the treatment of dental caries are of two kinds: 1st. The preventive treatment, or preservation from caries; 2d. The curative treatment, or rational therapeutics of confirmed caries.

The preventive treatment, or prophylaxis, includes all the rules of local hygiene intended either to check the production of the efficient cause or altering agent itself, or, in certain determinate cases, to neutralize its effects on the spot.

The curative treatment of confirmed caries consists: 1st, in the therapeutics of the various accidents caused by caries; 2d, in the practical operations having for their end the conservation of the organ and the reëstablishment of its usefulness.

There is here, as will be seen, no question of extraction, which does not, properly speaking, constitute a mode of treatment of caries, but is an operation directed to the suppression of the diseased organ. This operation, as well as the study of its indications and details of application, enters moreover into the domain of special operative medicine, which makes no part of the present work.

This chapter on the treatment of caries will therefore be confined to the study of the rules of prevention, as well as the various therapeutic methods; and we shall find herein the demonstration of this proposition, that in the

great majority of cases, even in the advanced stages, the cure is possible by a series of rational means based upon exact notions of the etiology and of the progress of the affection. Now, the whole of our investigations upon the nature of the malady considered as an alteration of a purely chemical nature leads us to this therapeutic conclusion, that, to cure it, the altering agent must be neutralized and the tooth removed from its further action; the restoration of the loss of substance which has been experienced is not possible by means of the tooth's own resources, but it may be imitated by the substitution for the absent portion of a material possessed of sufficient resistance and sufficiently inalterable to supply its place. This operation is *obturation* or *plugging*, which we mention here in a general way as the most common end of the treatment of caries.

A. Preventive Treatment. — The general means for the preservation from dental caries should be applied not to the tooth itself, whose constitution, after its complete evolution, can be modified by no artificial intervention, but to the medium in which it sojourns in the mouth, that is to say, to the saliva. The tooth, in fact, at the moment of its eruption, presents, as we know, the composition it retains thereafter during life, except, it may be, some slow and continuous modifications of its substance which confer upon it greater density and a harder consistency. This circumstance in part explains why the teeth of the aged ordinarily offer greater resistance to caries than those of the adult and the infant. Aside from its intimate structure, certain peculiarities diminish the chances of the development of caries; thus teeth well separated from one another are manifestly less

exposed by reason of the less facility which destructive agents have to originate and locate themselves in their interstices. This fact, long observed, has suggested to some specialists the idea of preventive extraction of one or two teeth in each jaw, the bicuspids, for example, so that the others may space themselves notably and not touch at any point. In this way we almost surely escape caries in the dental interstices and diminish the general causes of alteration. Without recommending such a sacrifice, we mention it as one which may be used in a mouth clearly exposed to active causes of caries whose chances of action we wish to reduce.

Some precautions relative to the teeth may nevertheless be taken as preservative; such are isolation by means of the file of caries situated on the proximate surface of a tooth, in order to avoid its contact with the neighboring tooth; the effacement, in cases of fracture, of the points and ridges capable of retaining alimentary débris or other agents of fermentation, etc.

The prophylactic means directed to the saliva or to the various conditions of the mouth have a much greater importance and an efficiency much better ascertained. They consist either in removing from contact with the teeth the destructive agents deposited thereon, or in neutralizing chemically their harmful reactions. Some examples will make our idea better understood.

Let us suppose an acute, febrile affection, a typhoid fever, for instance, which causes, as we know, a complete suppression of the salivary secretion and the deposit in a hardened state of masses of mucus at the surfaces of the teeth. If, by a too frequent negligence, no attention is paid during the sickness to the condition of the mouth; if the regular removal of the mucous crusts is neglected,

the teeth, at the moment of convalescence, after the removal of the fuliginosities, are found covered with spots of caries, stippled or in furrows, which generally spread with great rapidity to other parts of the organ. It is thus that numerous cases of caries are so often observed following affections of this kind. Now the preventive method is in principle very simple: it consists in the daily removal of the mucous crusts, followed by the application, several times repeated during the twenty-four hours, of an alkaline wash. This slight operation should be performed with a sliver of wood so shaped as to rub the surfaces of the teeth without risk of injury. For subsequent application we advise the use either of a thin paste of magnesia with water spread with a brush over the whole surface of the teeth and of the alveolar border, or better still of a mouth-wash of bicarbonate of soda. We reject entirely from this composition the presence of honey, a common ingredient in preparations of the kind, whose influence on the teeth is deleterious; replacing it by another substance sufficiently soft and viscous to hold the alkaline agent in contact with the covered parts.

The formula is as follows: —

℞ Bicarbonate of soda . . . . . 8 grams.
Mucilage of gum tragacanth . . . . 20 "
Mix carefully. Apply morning and night.

If a local condition of the mouth or a general affection of the economy has caused a change in the reaction of the saliva, exciting in it rapid fermentations, the preventive means consist in the most minute attention to cleanliness in order to remove fermentable substances or the ferments themselves from contact with the teeth, and the use of alkaline dentifrices to neutralize on the spot the

products of fermentation. Such affections are especially digestive, dyspepsias, gastralgia, etc., with viscous saliva, abundant whitish mucosities, in which these precautions are indicated.

As regards dentifrices themselves we shall state our conclusions in another publication treating specially of the hygiene of the mouth, but we may here say that, for the prevention of dental caries, the dentifrice should always be alkaline and pulverulent, and that its preparation should neither be trusted to perfumers nor to other dealers in cosmetics, but formulated by the physician himself, who will vary, according to the case, the dose and the nature of the active substances it should contain.

A dentifrice, for the special purpose we are now considering, should consist: 1st, of an inert excipient, powder of charcoal, carbonate of lime, pumice-stone, etc., reduced by grinding to an impalpable dust;[1] 2d, of an alkaline substance, bicarbonate of soda or magnesia; 3d, of an aromatic, an odorous essential oil.

We append a formula that we have been in the habit of using in cases of this kind: —

℞ Vegetable charcoal pulv. and washed, Carbonate of lime . . . . . āā 20 grams.
Red cinchona bark pulv. . . . . 12 "
Calcined magnesia . . . . . 8 "
Essence of mint . . . . . 5 drops.
Mix.

We may also, for such cases, use in connection with the dentifrice frequent alkaline lotions in the mouth; and

[1] Pulverized charcoal and pumice are regarded by American dentists as wholly unsuitable for use as tooth powders, from their wasting effect upon the enamel. — Tr.

we generally advise rinsing the mouth with natural Vichy water, or a solution of eight or ten grams of bicarbonate of soda to a pint of water.

Some practitioners have also advised rinsing with lime water or a solution of chalk; we have also used these, but their disagreeable taste has caused great repugnance; nevertheless, by taking care to add some strong aromatic to the liquid, recourse to them may still be had. These means have an incontestable effect; and in many cases we have been able to see caries, threatened during the course of certain maladies, entirely averted, or various alterations, developed during convalescence, suspended in their progress and converted to the condition of *dry caries.*

The prevention of caries, when caused by alimentary or medicinal substances, is, by following the same course, equally possible. Among injurious alimentary substances, sugar under all its forms should be placed first on the list; crystallized syrup, barley sugar, bonbons, honey, etc. We have seen how powerful this agent of alteration is in the mouth, and we are convinced that it should be held responsible for very many of the frequent cases of caries of the temporary teeth in children, who are allowed the immoderate and almost constant use of this substance.[1]

[1] We should also attribute, without doubt, the caries of certain domestic animals, the dog and cat, for instance, to the use of sugar. Moreover, caries of the teeth, in those animals which show it, presents the same characteristics as in man. In the horse, where it is very often seen, its development follows the same laws. It has, in fact, been remarked that it occurs either in the congenital fissures of the crown, or in traumatic lesions caused by foreign bodies, such as stones, in the food, and doubtless by means of fermentation at the points thus predisposed to it. From certain remarks of M. Trasbot it would seem also to be hereditary. Its advance and its end are the same; except that in the veterinary art the only resource is extraction, an operation always grave and difficult in the horse,

This fact is of still greater importance in the child at the moment of the eruption of its first teeth; and if these are attacked prematurely by caries, it can generally be attributed to the milk in the nursing-bottle, to paps richly sweetened, or to honey and other sugared preparations that too often replace the maternal nourishment.

These considerations as to the hygiene of the mouth in early childhood should be had, it seems to us, in serious attention, and every physician has been witness to the accidents and disorders so often occasioned by caries of the temporary teeth. It should not be overlooked, indeed, that these teeth are required to fulfill their purposes for a period extending from the sixth month after birth up to the twelfth year, when the loss of the last deciduous tooth usually occurs.

With the child, therefore, as with the adult, it is indicated to moderate or suppress the use of sugar; and here we speak of sugar that dissolves slowly and remains long in the mouth rather than the liquids or sweetened food whose passage over the teeth is comparatively rapid. We do not proscribe sugar, an important element in our alimentation; we simply protest against its abuse.

These warnings against the abuse of sugar apply also to the acid viands, fruits of various kinds and of doubtful maturity, such as lemons, oranges, apples, etc., whose

often bringing after it a complete incapacity for use. We cannot therefore be too urgent for the substitution for this method of some therapeutic endeavors, with the end, if not of preserving the organ, at least of arresting the progress of the malady and avoiding its results.

In other domestic species, the ruminants and the pachyderms, for instance, caries is never seen. It should be remarked, however, in this connection, that the life of these animals is but short, since they are killed for purposes of food before they have even reached adult age. Nevertheless, it is never met with in the wild races.

deleterious influence, as well as that of their acids, citric, malic, etc., has been seen above.

We would call attention also to the use of certain medicines: the mineral acids, employed sometimes with little precaution in the mouth, such as chlorhydric acid, especially dangerous; nitric acid, nitrate of mercury, and particularly alum. This last agent is employed commonly in the treatment of cynanche tonsillaris and pharyngitis, the different forms of stomatitis, etc., and we have seen its disastrous influence upon the dental tissues. We do not hesitate to declare that it should be almost absolutely rejected from the therapeutics of the mouth and throat, and that there should be substituted for it agents not less efficacious, but whose reaction is neutral; such as chlorate of potassa, borax, nitrate of silver, neutral perchloride of iron, etc.

Our remarks apply as well to the cosmetics, dentifrices, paste or pulverulent, whose reaction is acid. This reaction is due ordinarily to the presence of a notable quantity of pulverized alum. The preparations of which we speak, by reason of the very presence of this substance, have the property of admirably whitening the teeth, bringing them therefore into considerable favor. They have great influence in the production of caries, and this powder is responsible for the loss of many a tooth. It will therefore seem strange, as a lamented savant, Réveil, has remarked,[1] with reason, that the sale of cosmetics in general is not regulated by law in the same way as are pharmaceutical preparations, and that the acid dentifrices in particular are not relegated among the dangerous or injurious preparations.

[1] *Bulletin de l'Académie Impér. de Médecine,* vol. xxvii., pp. 865, 1160.

B. Curative Treatment. — The treatment of confirmed dental caries comprehends the totality of the therapeutic means applicable to each stage of the malady. This treatment is represented, as we have already stated, by the investigation: 1st, of the cure of the various symptoms and accidents which may arise under the influence of caries; 2d, of the preservation of the organ with restoration of its usefulness.

The cure of the symptoms of caries is effected by the employment of agents varying in their nature and mode of application, according to the different periods of the malady.

The conservation of the organ is attained by an operation that constitutes the last part, or termination, of the treatment, and which in a general way consists either in the *resection* of the diseased portion, in the case of superficial caries, or in *obturation* in deep caries. It follows from this that the radical cure of caries is reached after the cessation of the accidents, by *isolation*, that is, the removal of the remaining sound portions from the causes of alteration which may persist or be reproduced. This mode of treatment is, morever, perfectly in relation with the ideas we have developed of the causes and the physiognomy of caries. If ever the therapeutics of a disease have been able to declare its nature, it is clearly in this case, and the old Hippocratic adage, "*Naturam morborum curationes ostendunt*,"[1] receives here a new confirmation.

Our descriptions of the treatment applicable to the three successive periods of the malady should, to be complete, be followed by the exposition of the observations typifying the varieties of form and complications that may be presented by these periods themselves.

[1] Cures reveal the nature of diseases.

## § 1. *Treatment of the First Period.*

The treatment of caries, when it has attacked only the enamel, is ordinarily simple. The alteration is most frequently absolutely indolent, which explains why it often remains unsuspected, and its treatment then consists in a simple operation of which we shall presently speak. If it is accompanied by accidents, they always have their seat on the surface of the superficial layer of ivory exposed at the bottom of a depression of the enamel, and consist of painful sensations excited by the contact of some foreign substance: the impression of an acid liquid, sugar, or a temperature either too low or too high, etc. In this case the operation should be preceded by an appropriate therapeutic treatment, comprehending some astringent or caustic applications, whose effect is to excite, on the part of the over-stimulated pulp, a dentinal superproduction which leads to the closure of the canalicules, and consequently to insensibility of the ivory. The means appropriate to this effect are the applications of tannin, of carbolic acid, of creosote. If repeated applications of this kind do not suffice, we should have recourse to caustics or to the actual cautery. The caustics are in their order arsenious acid, chloride of zinc, lunar caustic, etc. We give the preference to arsenious acid, by reason of its relative insolubility, and its easy application in the form of fine powder.[1] Direct cauterization may be accomplished by means of minute instruments of various forms passed rapidly over the sensitive point.

[1] The use of arsenic for the purpose of obtunding sensitive dentine has long been abandoned in this country, for the reason that it is *certain death,* soon or late, to the tooth pulp. It is only used now when the death of the pulp is sought, and for any other purpose its use is absolutely unjustifiable. — Tr.

The employment of cauterization produces insensibility quickly, and the actual cautery immediately. This result is due in the latter case to the fact that the heat causes partial carbonization of the ivory, and of the canalicules and their walls, and the kind of eschar thus produced at once intercepts external sensations. The caustics attain the same result only after a prolonged application of several hours, an entire day, or even after several renewals. The astringents require a still larger number of applications. As to the mechanism of their action, it comes always from the external irritation, which, transmitted to the pulp, excites there the habitual production of secondary dentine.

The absolute insensibility of the carious spot having been thus attained, we may proceed to the final operation, intended to assure and perpetuate the cure. This operation varies according to the seat, the form of the cavity, and the nature of the tooth affected. If the caries occupies the lateral border of an incisor and if its edge is not well defined we should practise resection; if its form is regular and it has its seat upon a molar, obturation is especially indicated. Without here entering into the circumstantial details relative to these two operations, we should nevertheless give a brief description of them.

Resection is performed either with the file, or with gouges or rasps. Limited, as we have previously observed, to superficial caries of the lateral borders of the incisors, it is done generally with a flat and thin file inserted into the interstices of the teeth, and inclined, during its movements, towards the posterior face of the affected tooth, so as to form a flat, oblique surface slanting towards the back of the tooth without sensibly affecting

the anterior face. The cavity thus effaced is transformed into a regular surface which is susceptible of no further decay if care has been taken to leave no portion of the softened tooth substance whose presence may reproduce the malady. To this end the surface should be carefully examined with a fine excavator to ascertain its density; and if found not to be composed of entirely normal tissue, the filing or scraping should be carried still farther until the last remnants of the disorganized parts are removed. This operation is at times accompanied by a slight complication: at the moment when the instrument reaches the outer surface of the ivory, this, either from the absence of all previous treatment, or even in spite of such treatment, is found to retain a sensibility of greater or less acuteness, which is noticed particularly on contact with the air or with cold liquids. If this impression is slight we may leave to time the task of causing it to disappear; and, in fact, the ivory, taking on spontaneously a greater density, consequent upon the internal phenomena already noticed, opposes itself to the transmission of painful sensations. If the impression is acute, we may cause it to cease by the passage over the whole filed surface of a small olive-shaped or spherical cautery; one or two applications suffice, in the majority of cases, to allay all sensibility and thus assure the result.

The resection of the carious portion, an operation formerly much employed with the best results, is nowadays almost abandoned, from reluctance on the part of dentists to remove any portion of the enamel. This excuse is specious, and fails completely if it is considered that the cure is effected by the actual transformation of the cavity into a surface whose level corresponds, by the effacement of its borders, to the very bottom of the cavity and the sound portion of the ivory.

As for obturation, whose mode of application for this first period is the same as for the others, we will describe it further along in a general manner as the final treatment of caries. The cavity should be prepared in a special manner, regular, rounded, carefully freed from decayed portions and from foreign matter, in order to receive, upon the sound foundations thus laid bare, the material used for plugging.

## Observations.

Observation I. *Superficial Caries, insensible; Resection: Cure.* — A woman of thirty years, of delicate health, of Normand origin; teeth bluish white, friable, and many of them carious.

Caries of the mesial side of an upper right central incisor. This alteration, which had become perceptible only by its slight discoloration, had never caused the least disturbance. Application, for twenty-four hours, of a thin strip of India rubber, in order to obtain a slight separation of the teeth. Examination the next day discovered the amount of the caries, which had hardly penetrated the thickness of the enamel. Resection by means of a flat file, directing its action especially to the posterior face of the organ and removing from the whole surface of the inner border the entire thickness of the enamel. The operation terminated, the surface of the resection was explored by means of a bent probe, and perceived to be sensitive; at the same time a jet of cold water thrown upon the part produced considerable pain. Cauterization of the surface by means of the electric cautery. Immediate insensibility to the same tests.

Observation II. *Superficial Caries, slightly sensitive; Applications of Tannin; Obturation: Cure.* — Patient twenty years of age; good constitution, no previous abnormal condition of the mouth, or of the general health.

Accidental caries, developed in the centre of the first lower

left molar; had given pain when excited by the masticatory movements, the pressure of certain hard portions of food, the contact of acid liquids. The cavity, made regular in shape and enlarged at its orifice, did not extend beyond the external layer of the ivory. Exploration by means of a probe developed a painful sensation. Daily application for a week of a pledget of cotton covered with a thin layer of tannin in very fine powder. The first application gave considerable pain, by reason, no doubt, of the coldness of the substance. After eight applications there remained no sensibility at the bottom of the cavity, which was cleared and enlarged anew without pain, and finally filled with gold.

Observation III. *Sensitive Superficial Caries; Applications of Carbolic Acid; Unsuccessful; Cauterization with Arsenious Acid; Immediate Quiet: Cure.* — A young girl of seventeen, constitution excellent, no previous caries. The patient while eating felt a sudden sensation, as if caused by some hard fragment in the food, without doubt a minute spicule of bone, in the second lower left molar. From this time for several weeks mastication was always painful upon that side, and at each meal reproduced the same pain. Examination showed that this tooth had in the centre of its triturating face a minute excavation in form of a furrow or gutter, whose depth, when measured by a very fine stylet, did not seem to pass beyond the enamel layer. This minute cavity, enlarged at its orifice and made regular in shape by means of a small burr drill, was at the bottom sensitive to the contact of the instrument. A series of four daily applications of carbolic acid did not sensibly assuage the slight painfulness. Application of a minute quantity of arsenious acid upon a small pledget of cotton. The next day the insensibility was complete and the cauterization had given no pain. Plugged temporarily with a resinous plug and retained the plug one week. Plugged finally with gold. Cure.

### § 2. *Treatment of the Second Period.*

In presence of a caries of the second period the practitioner should, after the exact determination of the character of the cavity, clear it carefully from all foreign matters, then, by means of appropriate instruments, detach and remove the layers of softened dentine until the sound portions are reached. This delicate operation should be performed with the greatest precautions, especially on approaching the bottom of the cavity, that is to say, the part nearest the pulp. This point cannot be too strongly insisted upon, if the contact of the instrument causes much pain. The cavity will thus have been examined having regard to its general sensibility. If it has not previously caused pain and the exploration with the instrument causes no sensation, we may conclude that the dentine separating the bottom of the cavity from the central pulp has acquired a considerable thickness and density. All therapeutic treatment is in such case useless, and we may proceed at once to *obturation*. Nevertheless, cases in which immediate obturation is possible are quite rare, the patients in most cases awaiting the first symptoms of pain before consulting.

In the greater number of cases in ordinary practice the caries is therefore accompanied either by spontaneous pain, or by a more or less acute sensibility to the touch of the instrument towards the bottom of the cavity, whose soft and flexible tissue transmits to the pulp the impressions it receives. The problem to be solved for the complete cure in such case consists in restoring to this part the compactness and the resistance it has lost, and enabling it to afford subsequently a solid basis for obturation.

If the spontaneous pains have already been quite acute, the treatment should begin by a series of applications intended to obtund them. A host of preparations have been recommended with this end, and if we should give the formulas of all the mixtures which the dental pharmacopœia has supplied, the list would be enormous. It will be enough to say that they are for the most part composed of narcotics, essential oils, balsams, chloroform, ether, etc., etc. Moreover, at this phase of the malady, that is to say, in the absence of denudation of the pulp, we are able to calm the pains of caries with a certain facility. The simple application of a pledget of cotton or of lint, intercepting the contact of air and other external impressions, is sometimes enough. We generally use dressings composed of a plug of cotton rolled beween the fingers, of a proper size, dipped into one of the three following liquids: —

1st. Chloroform, Vinum opii, . . . . . āā 2 grams.
Tincture of benzoin, . . . . . 8 grams.

2d. Tincture of aconite, Hollands gin, . . . . . āā 2 grams.
Tincture of benzoin, . . . . . 8 grams.

3d. Chloroform, Creosote, pure, Vinum opii, . . . . . āā 2 grams.
Tincture of benzoin, . . . . . 10 grams.

The first two liquids, by their anæsthetic and narcotic action, produce an entire calm; the third owes its still more pronounced sedative action to the presence of creosote. As for the benzoin, its office in the three preparations is simply to give, by its precipitation in contact with the saliva in the meshes of the cotton, a sufficiently

great resistance against its further entrance, and enable the medicament to remain the required time and maintain the effect of its active ingredients.[1]

If any inflammatory element from the pulp or the periosteum complicates the caries, we may have recourse with greater efficacy to pure narcotics: a dressing soaked in Rousseau's laudanum, application of a pledget with extract of opium, or a slight layer of chlorhydrate of morphia, etc.

When all spontaneous pain is entirely extinguished, it remains to suppress the sensibility of the bottom of the cavity. The general method of obtaining this result is the employment of astringents, or of superficial caustics applied directly to the sensitive parts. We generally use for this end either carbolic acid or creosote, or, more frequently, tannin reduced to a fine powder, placed upon a small pledget of cotton and conveyed with it to the cavity.

The following are the formulas we have adopted in our practice: —

Tannin in powder,
Pulv. gum arabic, } . . . . . Equal parts.

The gum arabic has the effect of confining the tannin to the surface of the cotton and of better limiting its action.

Carbolic acid,
Pure creosote, } . . . . . Equal parts.

For the application of astringent liquids, a first dressing should be made of a minute quantity on a bit of cot-

[1] All these considerations relating to dressings, and the mode and duration of their application, etc., enter still more specially and with greater development into the text of our *Traité d'Odontologie*, in the chapter on *Médecine Opératoire*.

ton, and this should be covered with a second pledget soaked in an alcoholic resinous solution, tincture of benzoin, pure, intended to keep the first in place and at the same time to disguise its usually disagreeable odor. In the applications of tannin, the dressing charged with the substance should be soaked in a calming liquid, intended to retain it upon its surface and at the same time to lessen or annul the otherwise slight sensation of its action. The dressings thus made should be renewed every day for a short time. If there still remains a slight sensibility we should endeavor to quiet or check it by the application of narcotics, Rousseau's laudanum, or one of the liquid formulas above.

The number of applications necessary to a treatment, that is to say, to accomplish the absolute insensibility of a caries, varies infinitely, according to the degree of alteration and the functional disturbances of greater or less severity of the central pulp. In ordinary cases we estimate the mean duration of a treatment of this period to eight or ten applications, either renewed every day or at longer intervals, according to the cases.

Other substances have been proposed and used, empirically, it is true, to obtain insensibility of caries. We will mention among them alum, calcined and pulverized, applied in the form of a paste with various liquids. This agent, long extolled,[1] may in fact be applied in the treatment of caries, for we know, after our experiments, that it exerts no chemical action upon the tissue of the ivory. We should, nevertheless, if we wish to have recourse to it, be very sparing of this means, for alum, even calcined, does not cease to be sufficiently soluble to permit its dissemination throughout the saliva to the neighbor-

[1] See Lefoulon, *Traité de l'Art du Dentist*, 1841.

hood of the treated tooth, and to exercise upon the enamel of the contiguous teeth its appropriate altering action. We would in all cases prefer to it carbolic acid, which in its quality as a superficial caustic acts with considerable energy upon the ivory as an irritant. Its liquid nature and its solubility in water are, nevertheless, inconvenient, and it should not be employed except where the caries is well excavated, with prominent borders and able to retain it perfectly.

In some circumstances, a caries of the second period does not become insensible by the exclusive use of astringents, and it becomes necessary to have recourse to caustic applications, or the actual cautery. Such cases are, for example, caries of the neck of the tooth, and generally those which have rapidly advanced into the ivory. The sensibility of the caries is at times excessively acute, and the pains very violent which spontaneously arise from it. Astringent applications are without effect, and the ivory at the bottom of the cavity seems affected with a sort of constant hyperæsthesia. Then it is that we should have recourse to arsenious acid whose method of employment we shall examine further along, which often produces in twenty-four hours, and with a single application, complete insensibility, — or to actual cautery either with the iron or better still with the electric cautery.

Under the influence of a few applications of arsenious acid used with moderation, or after the passage of the cautery over the bottom of a non-penetrating caries, the ivory acquires, always by the phenomena previously described, a state of resistance and density due to the mechanism of condensing dentification thus excited. The caries then becomes insensible to all external influences,

and when this result is maintained without change for several days, we are justified in proceeding to final obturation, preceded by the habitual provisory operation.

The treatment of caries by astringent applications and caustics meets at times with an obstacle which we will describe; used rashly, or in too numerous or too frequent applications, they may excite inflammation of the pulp. The irritation of this organ being in this way carried too far, there rapidly take place, in lieu of a functional super-excitation, congestion and a veritable phlegmasia. Now the pulp, being shut up in a cavity closed in every direction, at once takes on a congestive compression accompanied by the most acute symptoms. The pain becomes permanent, continuous, of extreme violence, increases at the slightest contact and the least change of temperature, cold or warm. This complication, which left to itself might cause the loss of the tooth through mortification of the pulp and necessitate extraction, demands a special treatment. All irritating treatment must be at once stopped and opiates substituted, as morphine and laudanum, and frequently renewed.

If under this influence the symptoms disappear, we may take up again the previous treatment and carry it on to the realization of conditions favorable to obturation. If the pain persists, but one course remains, namely, trepanning the cavity of the pulp either at the bottom of the caries (removing the débris, and perforating the walls which separate it from the central organ) or at some more accessible point, as the neck of the tooth, when the situation of the caries is difficult of access. This operation, which results in the removal of the constriction in the pulp, gives place to an immediate comparative calm, and transforms the second period of the

malady into a case of penetrating caries calling for the peculiar treatment which remains to us to describe.

### Observations.

Observation I. *Caries of Second Period; Absolute Insensibility; Immediate Obturation; Cure.* — Man of thirty, good constitution. Caries of a second right upper molar, destroying a part of the posterior face of the triturating surface. This alteration causes no pain; the patient not perceiving it except by contact of the tongue, which enters the cavity; mastication even being possible on that side.

Examination with an instrument finds no point specially painful, hardly a slight general sensibility of the wall when scraped. The cavity, carefully prepared and freed from all foreign substances and from the fragments of softened ivory, is at once filled with amalgam (tin and silver, equal parts). At the end of two years the cure and the plug remained unchanged.

Observation II. *Caries of the Second Period, Sensitive, and had ached spontaneously; Treatment by Alternate Applications of Tannin and of Carbolic Acid; Insensibility; Obturation; Cure.* — A young girl of eighteen. Non-penetrating caries upon the anterior face of an upper right bicuspid; *pain when excited; some slight attacks of spontaneous pain.* Ten alternate dressings of tannin in powder and of carbolic acid. The first applications gave rise to dull pains. At the end of ten days the insensibility of the cavity was complete; filled with gold; cure.

Observation III. *Caries of the Second Period, Insensible; had never given any Trouble; Filled with Gold; Intolerance of the Tooth; Inflammation of the Pulp; Trepanning into the Cavity of the Caries; Destruction of the Pulp; Cure.* — Woman of forty. Several previous caries had necessitated extraction. Caries of the mesial border of the left upper incisor. The examination, preceded by separation with two applications of caoutchouc, enables it to be ascertained that the cavity is not sensitive; it has passed beyond the enamel, but appears to be still far distant

from the pulp; to the most careful examination it shows no connection with the pulp cavity. The pushing apart is continued for several days. This preparation causes slight sensibility of the two contiguous teeth.

Filled with gold, the operation causing no pain. One week after the obturation, there appear symptoms of inflammation of the pulp; continuous lancinating pains, increasing at the least contact and at the slightest transitions of temperature; application of a leech to the gum, which gives rise to a considerable flow of blood; comparative calm. Two days after, the pains begin again as acute as ever. The gold is removed; a new examination of the cavity discloses no communication with the pulp, the tooth has meanwhile taken on the grayish appearance which indicates threatening gangrene of the pulp.

Trepanning at the bottom of the cavity and exposure of the central organ dressed with narcotics. The next day all pain has ceased, but the tooth still remains sensible to extremes of temperature. Cauterization of the pulp with arsenious acid, one application sufficing for the death of the organ; subsequent simple dressings. Temporary filling kept in for one week without exciting reaction. New filling with gold.

The cure has remained after more than three years; but the tooth has kept its slight gray tinge, scarcely appreciable to the eye.

Observation IV. *Caries of the Second Period, Painful; Alternate Applications of Tannin and of Carbolic Acid; No Success; Cauterization with Arsenious Acid; Insensibility; Obturation; Cure.* — Miss B., eighteen years old, good constitution, no previous caries. Caries of the lower right molar, on the external face, which had given pain when excited, and also spontaneously in the way of transitory but sharp crises. Exploration shows no penetration to the pulp, but a very acute sensibility at the bottom of the cavity, and advanced softening. A series of eight alternate applications of tannin and of carbolic acid produced but a slight amelioration. A minute quantity of arsenious acid was then placed on the bottom of the cavity and retained for twenty-

four hours. The next day it was withdrawn, having caused a slight exacerbation of two hours' duration. In spite of the precaution of a double dressing, the mucous membrane of the cheek at the point corresponding to the caries showed a small eschar. Exploration with an instrument showed almost absolute insensibility. Four daily applications of carbolic acid, in order to complete the obtunding. At the end of the treatment, which lasted two weeks, all sensibility, from contact or spontaneous, was extinguished. Filled with a metal filling. After the lapse of a year the cure remains without change.

Observation V. *Caries of the Second Period, Sensitive and Painful; Dressings of Tannin; Unsuccessful; Cauterization with Arsenious Acid; Subsequent Insensibility; Obturation; Inflammation and Strangulation of the Pulp; Trepanning outside of the Carious Cavity; Destruction of the Pulp; Obturation; Cure.* — Mr. X., fifty years. Posterior caries of the first left upper molar; pain upon contact; some slight attacks of spontaneous pain, but without penetration to the pulp; the cavity is sensitive to the passage of an instrument. Eight daily applications of tannin render the surface of the caries totally insensible. Metallic obturation with a silver and tin amalgam. At the end of a fortnight appearance of the characteristic symptoms of inflammation of the pulp, with very acute and continuous pain, increasing on contact with a warm liquid, but quieted by cold or iced liquids. The removal of the filling was attempted without success by reason of the posterior situation of the cavity and the extreme hardness of the plug. Trepanned the pulp cavity from the neck of the tooth at the union of the external and anterior faces. Immediate cessation of the symptoms. Three successive cauterizations with arsenious acid complete the destruction of the pulp. Slight periostitis coincident with the third application. For four days dressed with laudanum, full strength; absolute cessation of periosteal inflammation. Obturation of the hole with gold. Cure at the end of four years unchanged.

Observation VI. *Caries of Second Period at Neck of Tooth;*

*Acute Spontaneous Pains; Extreme Sensibility; Previous Treatment by Means of Nitrate of Silver; Periods of Comparative Calm; Incessant Return of the Symptoms; Cauterization with the Electric Cautery; Complete Insensibility; Cure and Obturation.* — Madame de V., thirty years. Convalescent from typhoid fever; several very painful caries at the necks of the teeth. One of them, situated at the base of the external face of the first lower right molar, was extremely sensitive to the slightest influences. Various previous applications of nitrate of silver have brought periods of calm, but the symptoms incessantly recurred with the same acuteness. The cavity, carefully freed from foreign substances and fragments of softened ivory, was explored with an instrument, causing most acute pain. The caries, nevertheless, penetrated to but a short distance beyond the enamel, having the form of a transverse gutter.

Cauterization with the electric cautery carried rapidly over the bottom of the cavity. This application was excessively painful, but the pain rapidly ceased. Dressings of pure laudanum, in order to moderate the reaction. No ulterior symptoms. Three days after, a new examination reveals the return of sensitive points. A second cauterization, followed by laudanum dressings. Complete insensibility, which remained for several days. Preparation of the cavity by means of excavators, causing no pain. Filled with gold. Cure unchanged at the end of a year.

## § 3. *Treatment of the Third Period.*

The third period of caries, with penetration of the pulp cavity, is by far the most frequently presented in practice.[1] It is, in fact, at the beginning and throughout the duration of this period that there ordinarily appear the acute pains and the serious symptoms of the malady which bring the patient to demand aid of the dentist. The choice of the therapeutic methods should be pre-

[1] This may be true in France, but is far from being so in America. — Tr.

ceded by the minute examination of the caries and the mode of communication of the pulp cavity with the exterior. This exploration, made with an excavator, will allow, after the entire removal of foreign substances and layers of disorganized ivory, of the precise determination of the point where the exposure of the pulp has taken place. If the connection has been of recent date, which will be shown by its small size and especially by the recent period of the apparition of the first crises, we may at first think of saving the organ by allaying its inflammation and exciting the gradual production of enough secondary dentine to obliterate the orifice of communication, and thus reproduce a caries of the second degree.

This result, which should not be attempted except in the case of a recent denudation of the pulp without grave disturbance and without loss of substance of the tissue of the organ, is obtained by applications proper to allay the inflammatory element inseparable from its exposure to foreign influences, opiates, anæsthetics, or one of the mixtures hereinbefore mentioned, employed in dressings repeated every day. The cessation of the pain and the disappearance of all inflammatory symptoms are, in some cases, so rapid that the pulp, at once resuming its functions, produces a thin layer of dentine. In some circumstances it is useful, in order to set this process in action, or to aid in its realization, to follow the first quieting dressings with some astringent applications, such as tannin, burnt alum, carbolic acid, etc., but with the greatest moderation. Finally, when the thin layer of dentine has come and obliterated the opening, exploration shows that the bottom of the cavity is then represented by an uninterrupted layer of ivory in the way of molecular renovation, and if, by prolonging the use of the same means, this layer is suffered to increase in thickness and den-

sity, the malady becomes at last restored to the condition of a caries of the second period and susceptible of cure in the happiest manner by obturation with conservation of the pulp.

This phenomenon of obliteration of the opening of communication of the cavity of the pulp with the exterior, which is attained artificially, is effected spontaneously, as we have seen, in some cases, by the direct resistance of the organ, so that a caries, at the bottom of which this orifice has been found, may after some time cease to show it, and then those crises of pain which coincide with the exposure of the pulp also cease. This closed orifice may afterwards, if the action begins anew, again open and close, so that a caries, at this period of its progress, may present alternations of penetration and of reparation of the pulp wall at the same time with the accompanying production or cessation of the symptoms.

In the absence of phenomena of secondary dentification, excited or spontaneous, the practitioner finds himself in presence of a caries at the bottom of which the central cavity is open for a greater or less extent. The probe, in ascertaining this communication, perceives at the same time the state of the pulp and of the walls which inclose it. The organ may offer various peculiarities which sensibly modify the mode of treatment. Sometimes it has preserved its normal volume, but has undergone inflammatory conditions, either partial or generalized throughout its mass; at other times it has experienced an increase of volume either through the action of inflammation or by some organic affection producing a real hypertrophic tumor, as will be seen in the observations we shall publish further on. In other cases, it may have already undergone a diminution of volume conse-

quent upon partial gangrene, purulent discharges, or progressive atrophy. It is then found lodged in a point of the cavity of varying depth, or subdivided into bundles by the division of the cavity, or else so reduced to a mere pittance of itself as to occupy but a remote portion of the canal in the roots. Yet in these various conditions of the pulp the treatment is uniform: the organ must be destroyed.

This operation may be accomplished in several ways. The pulp may be at once removed by means of a fine probe, straight or curved, carried into the cavity and quickly revolved to detach and extract the tissue. This procedure, formerly common, seems applicable only to the incisors and canines, whose pulp, of small volume and fusiform, may be entangled with ease and sometimes at once wholly withdrawn. It presents, moreover, certain inconveniences: first, an extremely acute pain; and, second, whatever precaution may be taken, there is always danger of leaving, after the operation, some fragments still adherent to the vasculo-nervous fascicle of the dental canal, and susceptible of taking on subsequent inflammation.

In general we reject the brusque mode of extracting the pulp, which should be reserved for cases of the greatest simplicity, where the instrument can, with certainty, effect at one stroke the total removal of the mass.

Cauterization, with the actual or the electric cautery, has also been proposed and applied in those cases. We can speak of this only as we have spoken of the preceding method. In fact the operator, armed with a barbed stylet or with a minute cautery of proper form, is never absolutely sure of penetrating into every part of the cavity and completely destroying the organ. Moreover, so

small a cautery cools rapidly and soon becomes unable to perform its work if, for example, it is necessary to carry it around the whole circumference of a cavity like that of a molar. If the electric cautery is employed, the necessity of a double platinum wire does not allow the heated extremity to be small enough to pass through the opening of communication. The operation, besides being very painful, is not without danger. The patient, surprised by a very acute and sudden sensation, may, by a quick movement, present to the contact of the cautery some point of the mouth. Another inconvenience not infrequently results from the use of the cautery, namely, inflammation, through reaction, of the pulp or of the periosteum, phenomena which we will examine further on as complications in the treatment of caries, and to which the process just spoken of is peculiarly exposed.

The method of destruction of the pulp or of its fibres to which we give the preference is the employment of caustics. We do not speak here of the superficial caustics, carbolic acid, nitrate of silver, etc., applicable as irritants in the preceding stage, but of the caustics whose action is profound and destructive of the tissues.

The liquid caustics should rarely be used, as being difficult of management and application. In fact, it is only with difficulty that their action can be localized and moderated. If they are acids, as nitric acid, which has been proposed for this purpose, they have the inconvenience of producing upon the tissue of the tooth a direct alteration whose issue cannot be foreseen, and which necessarily, after several repeated applications, must have the effect of softening and causing to disappear the whole of the crown. If they are alkalies, as potassa, soda, baryta, etc., they have the inconvenience, by their great solubil-

ity, of dissolving in the neighborhood and producing disturbances about the gums, the cheeks, or the tongue. Yet we make a reservation in favor of one caustic liquid, the chloride of zinc, for some well determined cases, in which, in consequence of the form or the position of a caries, the application of a solid or pulverulent substance is difficult. It is clear that a liquid caustic, having the power of spreading itself and penetrating step by step into all the corners of a cavity, produces in it a more advanced and complete destructive action.

In cases where the application of a liquid caustic is indicated, we may have recourse to a mixture like the following.

℞ Deliquescent chloride of zinc,
Chloride of antimony, saturated solution, } equal parts.

Another form of application of chloride of zinc is Canquoin's paste, with which we may make a small ball or cylinder and introduce it into the very centre of the central cavity of a tooth, in such a manner as to destroy every fragment of the pulp. The chlorides used in a liquid state under such circumstances should be as neutral as possible, and their application made very moderately upon a pledget of amianthus or cotton, and isolated from the neighboring parts of the mouth by a layer of wax or a protecting dressing composed of a ball of cotton soaked in an alcoholic solution of resin.

The solid caustics seem to us, finally, the most suitable and those which should be most generally used. Among these we should always choose an agent which, insoluble in the saliva and without chemical influence upon the tissues of the ivory and the enamel, is at the same time capable of energetic action. These conditions, which are

not present, completely at least, in any of the caustics generally employed, powder of Vienna, caustics of Côme, of Landolfi, etc., are found united in one substance, *arsenious acid.*

This agent, whose original employment for the cauterization of the pulp goes back but a few years, and appears to have been first made in England, is very easy of application, sure and complete in its effect. In the *opaque* or *vitreous* condition, reduced to fine powder by trituration, its solubility in water and the saliva is but slight, it is without influence on the hard tissues of the tooth, and its caustic action is very energetic. It possesses, it is true, poisonous properties which may cause hesitation when it is proposed to use it in the mouth, but the quantity necessary for cauterization being infinitely smaller than the toxic dose, a carefully applied dressing, even if it were swallowed by accident, should cause no injurious effect. Nevertheless, its application in the cavity of a caries calls for certain precautions which should never be neglected. The dressing, charged with the substance reduced to impalpable powder, should be placed upon the very point of the exposure without sensibly exceeding the limits of the passage, and then covered with another pledget, intended, on the one hand, to keep up the cauterization, and on the other to ward off the neighboring portions of the mouth from possible contact with the arsenic. Sometimes, when the passage is free, that is to say, when the pulp, already receded to the bottom of its cavity, is not found at the opening, the application should be preceded by enlarging the orifice, so that it may receive and let freely pass the application, which should then be carried in a mesh of fine cotton charged with the powder.

The approximate dose of the arsenical powder necessary for a dressing demands some attention. As it is difficult in daily practice to exactly weigh the desired quantity, we advise a course which we habitually employ. The caustic reduced to a fine powder is introduced into a wide-mouthed phial with a carefully ground stopper. When we wish to use it we shake the phial in such a manner that a certain quantity of the powder may remain adherent to the lower face of the stopper, which has been ground rough ; this when drawn is found covered with a uniform layer of the substance, which, moreover, is the very finest of the contents. Then we carry over this surface the ball or mesh of cotton, which easily takes up in this way the necessary dose.

The use of arsenious acid reduced to powder is not the only method which has been proposed. It has been advised to unite with it some other powder, the chlorhydrate or the acetate of morphia, for example. The following is the formula : —

℞ Arsenious acid, pulv. } . . . Equal parts.
Chlorhydrate of morphia, pulv. }

Other methods consist in reducing the arsenic to a paste, in the following proportions : —

℞ Arsenious acid, pulv. } . . . āā 2 grams.
Chlorhydrate of morphia, pulv. }
Mucilage of gum tragacanth, q. s. to make a soft paste.

The first method, intended to lessen the pain of the caustic, has not seemed to realize this result, and according to our observations the painful effect of the arsenious acid has always been the same with or without the addition of morphine.

The second mixture, which we first employed, has been

entirely abandoned in our practice. We accuse it of rendering more difficult the obtaining the right quantity of arsenic ; moreover, it exposes it to solution much more easily than the dry powder applied, as we have said, on a small pledget of cotton moistened with an alcoholic tincture intended to make it adhere.

Under the influence of the arsenical application held in contact with the pulp for a variable period, which should, in our opinion, never exceed twenty-four hours, the dental pulp becomes covered with an eschar which at times does not affect the whole tissue but at others destroys it entirely. If the destruction is not complete, which is easily ascertained by the exploration of the cavity and the pain experienced on contact with the probe, the application should be renewed, having care to remove the eschar already formed, which would resist the further action of the caustic.

In certain caries with considerable volume of the pulp, those of the molars for instance, we may have to make three or four applications and sometimes more to obtain the entire destruction of the organ. For teeth of small size, or those whose pulp has already spontaneously experienced a marked shrinkage, a single application may suffice to secure its absolute and final disappearance.

This cauterization with arsenious acid ordinarily excites very severe pain, which occurs in the form of a crisis of varying duration of from half an hour to four or five hours. It is also proportional to the volume of the organ to be destroyed, and to its greater or less condition of inflammation. If the pulp is simply denuded for a certain extent without showing any manifest alteration of tissue, which may be known by the absence of any previous spontaneous symptoms, the pain may be very slight

or even none at all; if, on the other hand, the organ is inflamed through its whole extent, the pain may be violent and prolonged, at times affecting, like the pain of caries itself, the neuralgic form, radiated to the facial, cervical, or hemi-cranial regions, complicated in some cases with general symptoms, or with fever. We should advise, therefore, in practice, to precede every application of this kind by a number of dressings to calm the irritation of the organ and to bring it back, as far as possible, towards the normal condition: thus we shall lessen and perhaps entirely check the crisis resulting from this cauterization.

The dressings we usually employ previous to caustic applications are those which have been already formulated, and especially those containing creosote. Only after several applications of this nature, bringing on almost complete calm, do we begin the cauterizations.

The use of arsenious acid in a carious cavity sometimes produces certain complications. Thus when it is applied in a caries of the labial or lingual surface of a tooth, the part of the mucous membrane corresponding to these may, even through the protecting dressing, receive an eschar of greater or less extent. This slight accident is usually a matter of little gravity and is most frequently cured without further applications; yet, if the dressing has been applied with little care, it may occasion more serious disorders, accompanied by fluxions, erythematous patches of the cheek, and pains of greater or less severity. Analogous effects are caused in cauterization of caries of the necks of teeth, and in this case it is the dental periosteum, the gingival mucous membrane, and the alveolar tissue itself that experience the effects of the caustic, and become seats of inflammation

and disturbances, at times so intense as to cause the cessation of treatment for the caries and necessitate appropriate remedies. These complications may readily be avoided by a methodical procedure and moderation in the use of the caustic powder.

When the pulp has been thus entirely destroyed by one or more applications, we should be careful not to proceed at once to the obturation of the cavity, but should ascertain with certainty that no fragment of the organ has succeeded in escaping destruction in a difficultly accessible corner of the cavity. This fragment, so persistent, becoming immediately the seat of inflammation beneath the layer of eschars covering it, will enter upon suppuration, and the pus, contained in a cavity without issue, will penetrate through the foramen at the apex of the dental canal, excite periostitis, either general or localized at the end of the root, and all its consequences, sometimes so serious, phlegmon of the face, osteïtis and necrosis of the maxillary, etc.

This complication of periostitis may also be caused, without obturation, by the reaction excited in the pulp by one or several cauterizations. If, for example, the dressing is not applied immediately on the organ, or if it is insufficiently charged, it does not produce the caustic effect, but, as an irritant, develops an inflammation of greater or less severity. This accident, nevertheless, has not then the same gravity as in the case of non-penetrating caries, by reason of the always possible issue of the inflammatory products through the opening into the carious cavity; but it causes very acute suffering, which we should allay as quickly as possible. This is accomplished in such cases, not by calming applications, opiates or the like, which are generally insufficient, but by a new

cauterization, this time complete and absolute, which in a few hours causes the cessation of all the painful symptoms. This latter operation should often be preceded, to be final, by an enlargement of the opening in the central cavity, or the veritable trepanning of the bottom of the caries in order to obtain a perfect contact.

The inflammation of the pulp is not the only complication of the treatment of caries by caustics. There often occurs another which we have already noticed as consequent upon too early obturation, namely, *alveolo-dental periostitis.* This affection, which occurs spontaneously in the last stages of caries left to itself, and whose history belongs to another work, is characterized by certain peculiar symptoms: sensibility of the tooth to pressure, dull, continuous pain, slight loosening and noticeable elongation of the tooth, redness of the gum. If the inflammation is slight, we may easily allay it by means of opiates applied in the cavity of the caries, pure laudanum for instance, employed for several days in place of all other treatment. If it is more severe, we should resort to local blood-letting, as the application of one or two leeches upon the gum at the point corresponding to the affected root, and followed by warm lotions in the mouth in order to obtain a sufficient flow. Scarification of the gum at this point may be used instead of leeches. Under these influences the pain generally lessens with great rapidity, and the treatment may then be continued to the complete destruction of the pulp and cessation of all pain. At the moment when every symptom of pain has ceased the cure may be considered as completed, and nothing further remains to be assured of its persistence than proceeding at once to obturation.

If we now consider the state of a tooth whose pulp

has been destroyed and whose obturation has become possible, we are led to ask what is now its mode of nutrition and the reason of its continuance in the economy. We know by the anatomical data herein given that the nutrition of the tooth is effected in two ways simultaneously: the first and most important resides in the pulp; the second is represented by the periosteum. Now in the absence of the pulp, this periosteum, when in a state of health, may suffice, through its circulation proper and the intervention of the cement, to convey to the ivory sufficient material for its nutrition.

Phenomena of this nature permit, for some time at least, the continuance in the jaws of the teeth of the aged after complete atrophy of the pulp. Nevertheless we should say that in these pathological conditions, the dental periosteum, thus charged alone with the burden of nourishing the organ, sometimes reacts and becomes the seat of alterations which generally take a slow, chronic form. There then occur points of the periosteum with separation of the membrane by deposits of plastic lymph; the cement itself, as it were over-stimulated by its supplementary functions, becomes hypertrophied and the seat of rounded products under the form of small transparent and amber-colored masses.

The lesions are not always limited to the periosteum or the cement, and the alveolar border and the periosteum of the bone may themselves share in alterations of this character. We then often notice, under a subacute form, either a sort of bony swelling, simple osteïtis, or more frequently a kind of periostose, or plastic effusion between the periosteum and the surface of the jaw. These various accidents, while ordinarily wearing an indolent form, may accidentally pass to the acute condi-

tion, and become the occasion of grave disorders, as necrosis of the maxillary, phlegmons of the face, fistulas, etc.

These phenomena are, we must say, quite rare, and in the immense majority of cases, obturation meets, neither primitively nor consecutively, no obstacle of this kind.

Nevertheless, the tooth, deprived of its pulp and cured, does not always retain the external appearance it had normally. It often acquires a more or less marked grayish tint, which comes from the penetration into the canalicules of the coloring matter of the blood following upon the mortification of the central organ. This accident, unimportant for the teeth placed far back in the mouth, may become serious for those of the anterior region and exposed to view; therefore, in the treatment of penetrating caries of the latter, we should endeavor to preserve the integrity of the pulp by the proper therapeutic methods, or at least to avoid, by moderate and repeated cauterizations, the rapid gangrene which has seemed to us most apt to occasion the transportation of coloring materials.

Obturation, regarded as the last term or the complement of the therapeutics of caries, is meant to free the tooth in a complete and final manner from the ulterior causes of the progress and return of the affection. It thus completes the method of cure called *isolation*, the only rational one.

This operation, whose description does not belong to this investigation, is effected by means of various substances which should unite certain properties of resistance and of inalterability. In the first rank must be placed gold, — which should be used everywhere where its employment is not absolutely contra-indicated. Next come amalgams, metallic alloys, the various cements, etc.

The gold for this purpose should be absolutely pure. It is employed either in foil or in the sponge. We much prefer the foil.

To fill with gold, the cavity, having been cured of its sensibility, must be prepared in such a way as to permit the thorough packing of the gold. The too shallow borders must be slightly excavated by cutting into the sound ivory; if they are friable and liable to break, either during the operation or afterwards, they must be reduced by means of the file, so that the enamel may always be supported by a lamina of dentine of some thickness.

These precautions taken, a sheet of foil must be rolled in such a way as to form a sort of twisted ribbon, which should be passed quickly through the flame of an alcohol lamp to anneal it. This appears to us indispensable in order to make a compact and resistant filling. The sheet thus prepared is introduced into the cavity and pressed forcibly in every direction by means of proper instruments, so as to change it as it lies into a true solid ingot without the occurrence of any open space or the interposition of any other substance whatever.

The obturation, thus made by a practised hand in a cavity offering favorable conditions in other respects, may last indefinitely; it represents in truth the most radical means of preserving a carious tooth, therefore we give it the preference over every other. Nevertheless, the conditions that call for this operation are not always present, and there are cases where, whether through the size of the cavity, its form, its position, or by reason of the sensibility of the organ rendering it unable to support the pressure of filling with gold, we should have recourse to other means, and apply to the cavity certain substances reduced to pastes, which by setting afterwards

acquire a sufficient hardness. Such are the different amalgams and the various cements. We will not go into the history of these mixtures, which are innumerable, but will confine our attention to those we generally use.

In the well-established impossibility of filling with gold, the mode of obturation used by us most frequently is with the amalgam of a mixture of silver and tin. This mixture, formulated by us some years ago, after a series of trials, is composed of

| | | |
|---|---|---|
| Granulated tin,<br>Pure silver, | . . . . . | Equal parts, |

melted together and reduced to a fine powder.

This powder, mixed with a suitable proportion of mercury, forms a rather hard paste, which is introduced by gentle pressure into every part of a cavity prepared in all respects as in the preceding operation. This forms a very durable filling, taking a polish and not changing its color in a noticeable degree with time, as do the greater part of the amalgams used for this purpose, which by the action of sulphureted hydrogen become of a more or less intense black. Nevertheless the metallic gray color of the substance does not permit its use in the front teeth. For these, therefore, in case of the impossibility of filling them with gold, we must have recourse to other means. In such cases we should use one of the various white cements in common use. Among these we give the preference to the one discovered some twelve years ago by a French engineer, M. Sorel.[1] It is composed of a mixture of chloride of zinc and oxide of zinc made into a paste and in this form introduced into the cavity. It soon be-

[1] See *Comptes rendus des Séances de l'Académie des Sciences*, 1855, vol. xli., p. 784.

comes very hard, and if care is taken for a few minutes to keep away the saliva we obtain an excellent obturation, which retains its white color, is capable of being artificially colored to match the shade of the tooth, and is quite durable.

Other experimental cements have been used, such as mixtures of gutta-percha and silex, various resins, etc.

We have personally undertaken investigations in a certain direction, that of the hydraulic cements. Thus we have obtained, under certain circumstances and in a practical way, a double silicate of potassa and lime, which has acquired the hardness of stone. We shall make these facts known hereafter.

Without carrying these considerations further, whose development would exceed the limits of this treatise, we will say that in the actual condition of our knowledge we may divide the modes of obturation into three classes, which, in our opinion, are sufficient for the majority of cases in practice : —

First. Obturation with gold.

Second. Obturation with metallic pastes.

Third. Obturation with Sorel's cement.

Whatever may be the material employed for obturation, certain conditions must be found united. It is necessary that the tooth be rendered absolutely insensible to all external influence and deprived of all spontaneous pains. Still further — and this applies more especially to cases of caries of the third period — the final obturation should be preceded by a temporary one, retained for some time, constituting a proof of cure.

A great number of substances may serve for this preliminary operation : wax, gutta-percha, etc. We confine ourselves in cases of this kind to a simple ball of cotton

soaked in an alcoholic resinous solution, such as tincture of benzoin, or better, the following mixture: —

| | | |
|---|---|---|
| Tincture of benzoin,<br>Purified resin, | . . . . . | āā 20 grams. |

Alcohol, q. s., to obtain with heat a syrupy solution.

This mixture, which is precipitated in the meshes of the cotton, forms a solidified mass, a complete plug, entirely sufficient to test the tolerance of the cavity. This precaution of preliminary obturation seems to us to be of the greatest importance when there remains the least doubt of an absolute cure. It often happens, in fact, that, in the absence even of every remaining fragment of the pulp, the tooth, upon the mere contact of the immediate metallic obturation, at once takes on inflammation of its periosteum.

These complications, when they occur immediately after metallic obturation, preceded moreover by rational treatment, are not always caused by pure and simple intolerance of this organ. They may also result from traumatism, occasioned by the operation of excavation as well as of filling. This last is especially true of filling with gold, which necessitates strong and prolonged pressure; therefore, as we have observed, it should be done with certain precautions, or replaced by some other method in the case of caries which has reached the last period. There are met, also, cases of caries complicated with chronic periostitis, which can endure no metallic obturation whatever, without taking on inflammatory reaction; we should then have recourse to provisional obturation with the organic materials, gutta-percha, the resins, etc., taking care to renew them as frequently as may be necessary.

From the preceding considerations relative to obturation as a general mode of treatment, it follows that this operation, aside from the material employed, may meet on the part of the dental organ two kinds of intolerance, namely, that of the pulp, and that of the periosteum.

The *intolerance of the pulp*, which we have seen to be excited in caries of the second period through a thick wall of dentine, finds its explanation in penetrating caries in the persistence of fragments of tissue, sometimes extremely minute but able to take on inflammation, to suppurate or to vegetate beneath the filling. Under such circumstances the theory of the treatment seems quite simple: namely, to destroy by the means indicated the last vestiges of the organ and attempt a new obturation. Such a procedure is, however, at times impossible, as in a caries with a difficultly accessible orifice, in which the dressings or other treatments cannot be carried far enough. We are sometimes forced, in such cases, in order to obtain tolerance, to make an incomplete plug, that is to say, the application of a substance, metallic or other, perforated with a canal, which, giving constant passage to the inflammatory products, however slight they may be, avoids the appearance of any acute symptoms. This modification, a real application of surgical drainage to the therapeutics of caries, is accomplished either by drilling into the filling already completed and hardened, by means of a fine drill, or by introducing into the filling itself a fine tube of platinum, an actual drain, which serves to establish and maintain the communication of the cavity of the pulp with the exterior. In the cases, finally, where these two modes of drainage are difficult, we may substitute, after the complete obturation of the cavity, the perforation or trepanning of the cavity of the pulp through the wall of the ivory at the neck of the tooth.

The *intolerance of the periosteum* results from two special causes: sometimes it is due to the almost direct irritation occasioned by the material used in obturation, in the case where it has been placed in the depths of the dental canal in the neighborhood of the foramen; sometimes the irritation is direct, caused, for instance, by the impressions excited by the variations of temperature upon the whole organ, impressions caused or singularly favored by the presence of a metallic body of greater or lesser size. In the first case, the thing to be done consists in carefully avoiding the penetration of the filling materials into the root canals; and for this end we have been in the habit of applying to the bottom of the carious cavity and at the opening of the pulp cavity a layer of tin foil, folded several times, upon which the obturation is to be placed. In the second case, if the intolerance is persistent, which is often due to the presence of certain points of chronic irritation of the periosteum, excited by the procedures of the obturation, we should have recourse to the removal of the filling, following this by sedative applications, and afterwards introducing another substance more easily tolerated, such as the non-metallic cements, or the organic substances themselves, gutta-percha, and the like.

Nevertheless we would add that these periosteal complications are generally far from being so acute as to necessitate active intervention, and there are very many cases where obturation stirs up, on the part of the organ, only a slight local irritation of the periosteum, either at the apex or at some other point, having for its sole effect the appearance of a minute furunculous abscess upon the corresponding point of the gum. This small abscess, which is frequently not perceived by the patient, gives rise to a narrow persistent fistula, whence issues an ex-

ceedingly small quantity of purulent matter, becoming thus a veritable drain whose presence restores to the tooth all its insensibility. A great number of persons owe to this peculiarity the absolute indolence of a caries complicated with periostitis and the restoration of the uses of the affected tooth. If, afterwards, the fistulous orifice becomes obliterated, acute symptoms reappear. These considerations should not be lost from view, for in practice it is possible to provoke a fistula, or to reopen one accidentally closed, and thus restore the peace due to its presence. We cite an example of this in the observations at the end of this chapter.

At the extreme period of the malady, various circumstances may yet occur which may give a rather different appearance from this which we have described as the type.

Thus a penetrating caries may be found without the least vestige of a pulp, which has entirely disappeared from the cavity. The malady in this case does not give rise to any one of the symptoms peculiar to the dental pulp, but often shows those which belong to periostitis, ordinarily passed to the chronic stage. In such a case, the tooth is sensible to pressure and to the action of mastication, so that it does not suffer its functions to be carried on with regularity, and the dental arch of this side, through inaction, becomes covered with masses of tartar.

It is in such a case alone that we observe the coincidence of a deep and old caries with the production of abundant tartar, which here represents only a consecutive and secondary phenomenon.

The process of the production of this form of caries is as follows: The pulp, at a given moment, denuded and doubtless vigorously attacked in its vitality by general

inflammation or spontaneous gangrene, has undergone an entire drainage of its substance, and a complete disappearance extending even to the remote vessels and nerve branches contained in the root canals; then the alveolo-dental periosteum, up to this time sound and unaffected, becomes exposed at the apices of the roots by this open way to the influence of external agents, and is inflamed. This accident, localized and kept at this point during a period of time often of great length, is followed by various complications: fungosities, cysts, sub-periosteal abscesses, etc. The practitioner then finds himself in presence, not of a simple caries in its third period, but of one situated, so to speak, at the extreme limit, and complicated by a more or less advanced form of permanent periostitis. The treatment should then be addressed especially to this latter affection, in the endeavor to restore to the tooth the tolerance of the obturation.

Beyond this last form of caries and its various complications may be grouped still other and different cases, in which, the malady having attacked the crown and caused its entire loss, there remain in the jaw nothing but the roots in their alveoli. These roots are at times indolent, if the alteration has reached a period of rest, sometimes painful if the softening has affected directly or indirectly the periosteal membrane.

The inflammation of this may then take on all the forms and be accompanied by all the complications. In this last stage the intervention of art is greatly restricted; we may indeed endeavor still to calm the pain by opiates; we may even, in some favorable cases after a rational treatment, attempt the obturation of the roots themselves and retain them for still a time longer in the economy; but most often the disease is beyond ordinary

remedies, and then the last operation is formally indicated, namely, *extraction*, which should be reserved for such extreme cases as are absolutely determined to be incurable.

It follows from these facts, from the point of view of the results of the treatment of caries, that the curè, common and easy in the first two periods of the malady, is a little more difficult in the third, and in the last phases of this period quite difficult or uncertain.

### Observations.

Observation I. *Penetrating Caries with Living Pulp, presenting a slight Degree of Inflammation; Destruction of the Organ by Means of Caustics; Obturation; Cure.* — Mr. D., forty years, chronic gingivitis and several previous caries.

Caries of the anterior face of the lower right second bicuspid situated in the interstice and near the neck; penetration of the cavity of the pulp; the living organ projecting slightly into the opening of the canal of communication.

Three or four previous crises; acute pains upon changes of temperature and upon suction.

Two preliminary sedative applications of a liquid narcotic creosotized.

A first canterization with arsenious acid is made to the orifice of the canal. This gives rise to a moderate crisis of pain, which lasts about one hour.

The next day the local sensibility has greatly diminished. The opening being very narrow we enlarge it by means of an instrument, causing an acute pain upon contact of the pulp.

Second application of arsenious acid on a pledget of fine cotton; this causes but slight pain during the day. The pulp then appears completely destroyed, nevertheless exploration with the probe discovers in the central cavity some remains of the living organ, and a slight complication of periostitis occurs. Removal

of the last remains of the pulp by some back and forward motions of the probe.

Application of pure laudanum, renewed for three successive days, at the end of which time the pain has disappeared and the insensibility of the cavity is complete. Filled temporarily; after one week, filling removed and finally filled with gold.

At the expiration of a year and a half cure found unchanged.

Observation II. *Penetrating Caries with Partial Disappearance of the Pulp; Complete Opening of the Cavity and Destruction of its Partitions; Obturation; Cure.* — Miss D., eighteen years, good constitution; two previous caries filled after treatment.

Posterior caries of a lower right first molar; penetration of the pulp with inflammation; frequent crises of pain; very acute sensibility upon the least external contact. The exploration of the cavity discovers the pulp at the orifice of the canal of communication. Several sedative applications succeed in causing the pain to cease entirely.

First application of arsenious acid to the orifice of the canal. This at the end of an hour gives rise to a slight pain. The next day, exploration with a probe finds no more sensibility at the level of the opening, but beyond are discovered clefts in which are found some fragments of the pulp, still painful to the touch.

By means of a sharp excavator we succeed in opening the cavity of the pulp freely at the bottom of the caries. This operation, very painful on account of the condensed tissue of the ivory and the difficult position of the caries, enables us soon to uncover entirely the central cavity, where the probe makes known the presence of partitions with subdivisions of the pulp tissue.

Cauterization with arsenious acid over the whole exposed portion of the organ.

Very acute pain, and the next day acute periostitis.

Opiate dressings; and application of a leech to the gum over the root of the affected tooth.

Progressive cessation of the inflammation during six days.

Temporary obturation with gutta-percha, retained for a week.

Final obturation with amalgam, and cure without change at the end of eight months.

Observation III. *Penetrating Caries; Preservation of the Pulp; Cauterization with Arsenious Acid; Want of Success by this Means; Application of Liquid Caustics; Cure.* — Mr. M., twenty-five years. Accidental caries of the upper left second bicuspid. Exposure of the pulp at the bottom of the cavity over a large surface.

Painful crisis for four days.

Sedative applications for two days, which cause a complete arrest of the crisis.

Cauterization with arsenious acid for twenty-four hours. The application caused excessive pain lasting for six hours.

On a fresh exploration the pulp is found to be notably receded and is no longer to be reached by the instrument except at the bottom of a broken and irregular dental canal. The passage is enlarged for a half or two thirds the length of the root by means of a drill.

A new arsenical application brings no manifest result, and the probe discovers still other fragments of sensitive pulp in the dental canal.

Cauterization with a small pledget of fine asbestos soaked in a mixture of chlorides of zinc and of antimony. This application, having caused no sensation, removed the next day, is found to have removed the last traces of sensibility; the whole extent of the canal examined with a probe is found free.

Temporary obturation with a ball of cotton soaked in a concentrated tincture of benzoin and resin, retained a week.

Final obturation with gold; cure lasting for two years.

Observation IV. *Penetrating Caries with Entire Disappearance of the Pulp; Acute Periostitis; Treatment by Opiates; Cure; Obturation.* — Mr. de N., sixty years, good constitution, some previous caries variously treated.

Posterior caries of a lower right second bicuspid. Easy penetration of the instrument into the cavity of the pulp and the dental canal, where there is found no trace of this organ. Acute periostitis; loosening of the tooth; very acute soreness on pressure; real lengthening; no pain upon changes of temperature.

Daily dressing with pure laudanum for a fortnight; progressive cessation of the symptoms.

Temporary obturation with gutta-percha, retained a week.

Final obturation with gold, and cure which has lasted without relapse for four years.

These four primary observations relate to the cases most frequently presenting in practice: exposure of the pulp; regular destruction of the organ, followed by obturation and radical cure.

These facts could be multiplied, as they are, so to speak, of the current practice; but, wishing to present in this work only typical observations, we proceed to give other examples of caries with various complications.

Observation V. *Penetrating Caries with Entire Disappearance of the Pulp; Chronic Periostitis; Obturation; Return of the Symptoms; Artificial Fistula made at the Level of the Roots and retained for several months: Cure.* — Miss B., twenty-five years, good constitution, no previous treatment of dental caries.

A vast penetrating caries on the masticating surface of the lower right first molar. Chronic periostitis dating back several years, entirely preventing every function of the mouth on that side, with return about every two months to the acute state, and crises accompanied by slight swelling of the cheek, sometimes ending in a small gingival abscess. No trace of the pulp remaining.

Dressings with laudanum for a week. Gradual diminution

of the pains, and subsequent complete cessation of the symptoms. Metallic obturation.

At the end of a week return of an acute crisis identical with the previous ones.

Without interfering with the filling, on the external surface of the gum at the usual pointing of the abscess, upon the point corresponding to the position of the root, a minute crucial incision is made to the bone. With a small gouge we remove the lamella of bone, completely exposing the roots themselves. Afterwards we insert into the opening a bit of cotton, soaked in laudanum, as a seton. The application is renewed every day.

In two days all pain has ceased. We retain the seton for two months, renewing every day, and then leave the tooth to itself.

Two years after the patient is seen again, and the artificial orifice is found as left, and to discharge about once a day a drop of pus.

No relapse has occurred, and mastication has been reëstablished on that side.

Observation VI. *Penetrating Caries with Disappearance of the Pulp; Chronic Periostitis and Constant Flow of Pus through the Dental Canal and the Carious Cavity; Obturation, retaining a minute Open Passage through the Filling; Accidental Obliteration of the Canal; Return of the Symptoms; Reëstablishment of the Canal; Cure.* — Mr. B., twenty-one years, excellent constitution, penetrating caries of the anterior face of the upper right first molar; total disappearance of the pulp.

The probe penetrates even to the dental canals without meeting any obstacle. The patient complains of nothing but a slight sensibility to pressure of the jaws and difficulty of mastication.

The cavity gives vent to a fetid liquid in small quantity, whose constant flow troubles the patient. Exploration with a probe

covered with cotton discloses a little purulent and offensive moisture.

The canal of communication is freely opened by a drill, through the canals to the neighborhood of the apices of the roots. Sedative applications each morning for two weeks continuously (creosoted mixture).

At the end of this time the sensation upon pressure is considerably lessened, and mastication is again rendered possible. Nevertheless, there still seems to exude through the cavity a slight amount of fluid. Temporary obturation with a pledget of cotton soaked in a saturated tincture of benzoin.

In a week intolerance of the plug is shown by the return of acute periostitis.

The temporary filling is removed and sedative dressings are reapplied for several days.

Metallic obturation perforated with a minute canal intended to give exit to the liquids coming from the periostitis at the apex.

All symptoms cease entirely.

After about two months the patient comes back to consult us: a new access of acute periostitis has come on. In examining the opening left in the filling, although it was situated in the upper and most inaccessible part we found that it had been closed by the penetration of some foreign substance. The probe passed into it opens the canal again.

The calm following this slight operation has continued without interruption for about a year, the patient taking the precaution now and then to pass a fine stylet into the opening to avoid another obliteration of the passage.

Observation VII. *Penetrating Caries; Gangrene of the Pulp; Chronic Periostitis of the Apex with Constant Flow of Pus through the Canal; Temporary Obturation; Return of Acute Periostitis; Final Obturation with Drainage by a Minute Tube of Platina; Cure.* — Mr. A., thirty years, deep cavity on the triturating surface and outer side of the lower right first

molar; complete inaction of that side and great accumulation of tartar; no previous swelling; slight sensibility upon percussion. Exploration with the probe permits the penetration without resistance to all parts of the cavity of the pulp, entirely destitute of every trace of that organ.

The patient utterly refuses extraction, and desires a cure which shall permit the return to use again of that side and the suppression of the disagreeable odor caused in the mouth by the tooth.

In fact, the probe furnished with a small bit of cotton rubbed about the cavity brings out a little black and fetid sanies.

A series of fifteen daily dressings with carbolic acid is applied throughout, even to the apices of the roots. The odor, after this, seems to have ceased, but the flow is not entirely cured.

A temporary obturation of gutta-percha kept on for a week produces a return of the acute symptoms. Upon being removed this discloses below it a grayish moisture without odor. We then refill the tooth with amalgam, taking the precaution of first placing a small tube of platina, reaching from the lowest point of the caries outwards towards the cheek and at the neck of the tooth, of about half a millimetre in diameter, over which we place the metal, and which keeps up free communication between the centre of the pulp cavity and the exterior.

The obturation is then easily tolerated, and the patient, seen after ten months, has recovered the use of that side and experienced no pain.

OBSERVATION VIII. *Penetrating Caries; Partial Destruction of the Pulp; Cauterization; Chronic Periostitis; Suppuration through the Dental Canal; Metallic Obturation; Acute Symptoms; Trepanning of the Tooth at its Neck; Preservation of the Artificial Opening; Cure.* — Mr. De R., fifty years, good constitution, several previous caries. Large caries developed on the posterior face of an upper left first molar near the neck; pain for several months under the form of transient

crises. The last attack lasted four days; the patient had noticed that, during the attacks, the tooth was sensible to pressure, rendering mastication on that side impossible; no previous swelling. The exploration of the caries, quite difficult on account of its situation, indicates the persistence of some fragments of the pulp at the bottom of the cavity, and the signs observed indicate the existence of a slight periostitis at the apex.

Cauterization with arsenious acid.

The application gives rise to slight pain, and a new exploration permits the easier penetration of the creviced and irregular cavity without exciting pain.

Temporary obturation with gutta-percha, retained a week.

No pain having occurred, at the end of this time metallic obturation is substituted for the gutta-percha.

After several days the patient complains of acute pains characterizing acute periostitis. Attempts at removal of the filling being of no effect on account of the difficultly accessible seat of the caries, we resolve to open the cavity of the pulp by direct trepanning of the tooth at its neck. This opening was made at the angle of union of the anterior and outer faces of the tooth by means of a drill.

Through the canal thus obtained we introduce every day a bit of cotton fibre soaked in pure laudanum.

The symptoms gradually cease.

An examination of the centre of the tooth by means of a flexible probe through the artificial opening discloses no remains of the pulp.

We decide to leave the passage open.

After two years the patient was again seen, and had suffered no relapse; his tooth, entirely insensible, performed its functions as well as the others.

The observations VI., VII., VIII. relate to cases of cure of caries by means of drainage. In the first, by

means of perforation directly through the metallic filling; in the second, by the introduction into the filling of a small tube or gutter of platina; in the third, by opening the canal into the pulp cavity at a point easily accessible, and keeping it open.

Cases of this kind represent exceptional cases, in practice, but they serve to prove that caries, even the most advanced, and accompanied with periosteal complications, are still capable of cure with restoration of the usefulness of the affected tooth.

In some cases of this kind, we should say, the operations just referred to remain without result, and the periosteal lesions persist or are aggravated in a way to leave no hope of cure. The story of these new complications, belonging to the special description of affections of the periosteum, does not enter into the purpose of the present work, and besides, the practitioner often finds himself at such times under the necessity of extracting the tooth as a last resort. Let us add, nevertheless, that such necessities should be very infrequent, a minute and attentive treatment being able, as we see by these examples, to accomplish, even in such grave cases, a complete cure.

Observation IX. *Penetrating Caries, with Total Disappearance of the Pulp; Polypus of the Gum included in the Cavity of the Caries; Absolute Insensibility of the Tooth; Excision of the Polypus; Temporary followed by Final Obturation; Cure.* — Miss S., eighteen years, lymphatic, several previous caries necessitating extraction. Vast cavity on the anterior face of upper left first molar; no pain. The cavity is filled with a soft, fungous, reddish mass, which examination shows to arise from the gingival border. It is a polypus of the gum; we at once remove it with pincers.

The exploration of the cavity by the probe shows the penetra-

tion of the cavity of the pulp and the total absence of that organ. Absolute insensibility of the parts; the caries is black and almost dry, with a hard and resistant surface.

Two dressings with tincture of benzoin. Temporary obturation retained a week. Final obturation. Cure.

Observation X. *Penetrating Caries complicated with a Polypus of the Dental Periosteum; Excision of Polypus; Regular Treatment of the Caries; Obturation; Cure.* — Mr. L., thirty years, good constitution, several previous caries variously treated. Caries of the anterior face of a lower left first molar. The cavity, which seemed to have attacked two thirds of the crown, is entirely filled with a rounded, projecting mass, almost spherical. The tissue is red, fungous, and bleeding at the slightest contact. The tooth has been in this state for about a year, causing absolute impossibility of mastication, and painful crises occur about every month.

The examination of the tumor shows that it belongs neither to the pulp nor to the gum. The probe can push aside the mass and penetrate below it, passing over the whole surface of the cavity; the gingival border, notably depressed at the position of this tooth, has evidently receded from its neck, and an instrument introduced into the interstice between it and the second bicuspid easily follows the border of the gum until at one point it meets a small soft adherence, contact with which gives motion to the tumor. It is therefore a polyp of the periosteum. We remove this tumor with the forceps; slight pain; little hemorrhage. Dressing with laudanum. The next day examination shows a communication with the living pulp.

Cauterization with arsenious acid, renewed for three consecutive days. Simple dressings of opiates. Temporary obturation for eight days. Final obturation. Cure.

The patient, seen again after a year, has had no relapse either of pain or of periosteal tumor.

Observation XI. *Penetrating Caries with Hypertrophy of the Pulp of the Size of a Large Pea; Excision of the Tumor;*

*Cauterization of the Pedicle and of the Whole of the Pulp; Obturation; Cure.* — Mr. B., forty years, good constitution, deep cavity of the upper right second molar, isolated by the loss of the preceding tooth. The cavity is filled by a globular, reddish mass, which clearly belongs neither to the periosteum nor to the gum. It is a hypertrophied tumor of the pulp. No painful crises; impossibility of mastication, and pain at the least contact of a foreign substance on the tumor.

We remove this mass by a simple section of the pedicle at the point of the orifice of communication of the canal with the central cavity. The remaining portion at once gives out a flow of blood, which is stopped at the expiration of about twenty minutes only by an application of cotton saturated with perchloride of iron. The next day cauterize the pedicle with arsenious acid. The day following a new application is necessary.

Four consecutive dressings with mixture of laudanum. Temporary obturation, retained a week. Final obturation. Cure still good after four years.

The last four observations complete the series of types of penetrating caries whose treatment we desire to explain. They show that caries, apparently desperate, with complications of various morbid productions, and generally considered as beyond all resources of art, are still curable by the use of appropriate rational methods. Very many other forms may be met with in daily practice; but it seems to us that they may nearly all be relegated to one or another of the different types here presented.

We believe, then, that we have demonstrated the proposition set forth in the beginning of this work, namely, that dental caries, in the actual state of the science, may be considered as curable in the great majority of cases.

## GENERAL CONCLUSIONS.

The majority of the questions raised in the foregoing work may be summed in the following propositions: —

I. Dental caries is a purely chemical alteration of the enamel and ivory of the teeth.

II. It always progresses from the outside of the organ inwards; there exists no example fairly proved of *internal caries.*

III. Dental caries is *one.* The varieties of form and color depend upon simple secondary variations in the nature of the altering cause, the progress and the duration of the malady.

IV. The anatomic lesions peculiar to caries succeed one another in three regular periods of the malady: lesions of the enamel, of the ivory, of the cavity of the pulp.

V. Lesions of the enamel consist, after the removal of the cuticle, in a purely passive chemical disorganization of the prisms composing its tissue.

VI. Lesions of the ivory, consisting likewise in a chemical decomposition of its elements, may sometimes, though rarely, remain passive, but most frequently they determine in the tissue phenomena of reaction that manifest themselves by the appearance of a cone or white zone, formed by a mass of canalicules obliterated in consequence of a formation of secondary dentine.

VII. This formation of the *cone of resistance* may be

followed by that of minute masses or bonelets of secondary dentine, occupying either a part or the whole of the central cavity of the tooth, and causing a proportionate retreat of the pulp.

VIII. The invasion of the central cavity by caries produces in the pulp a series of inflammatory symptoms ending in the destruction of the organ, so that the crown, henceforward without power of resisting the alteration, is rapidly softened and destroyed.

IX. As to the further alteration of the roots the caries is absolutely passive, and excites no other morbid symptoms than those that are peculiar to the dental periosteum and the neighboring parts.

X. The tooth attacked by caries does not remain passive and inert, but may in some measure undertake to resist its action by the phenomena of *condensing dentification* of the ivory.

XI. The agent of dental caries is the saliva become the medium of acid fermentations, or the vehicle of foreign substances susceptible of altering directly the tissues of the ivory and the enamel.

XII. The buccal cavity and the saliva may normally present this disposition to fermentations, and then caries occurs in the state of perfect health. This disposition may also be transmitted by heredity to the family and the race.

XIII. Most frequently the fermentescible aptitudes of the mouth depend upon local or general morbid circumstances causing modifications either in the mode of secretion or in the very composition of the salivary liquids.

XIV. The various conditions of conformation and of structure of the teeth act powerfully as predisposing causes on the development and the progress of caries.

Thus, this alteration, which generally spares smooth and polished surfaces, shows itself almost exclusively either in the dental interstices, or in the holes, furrows, grooves, presented by the crown; places where chemical action may be most easily occasioned. These circumstances explain the production of caries at the same points of two corresponding teeth on opposite sides, the anatomic predisposing constitution being reproduced in the homologous and contemporaneously developed teeth.

XV. The number and gravity of caries are in inverse ratio to the resistance of the dental tissues, and in direct ratio to the activity of the fermentations of the mouth or the energy of the destructive agent.

XVI. Caries can be caused artificially by imitating the conditions of alteration that the mouth itself may present. It then offers the same characteristics as the morbid caries, with the exception of the phenomena of the organic resistance.

XVII. The intimate mechanism of the production of caries is a simple solution of the mineral and calcareous salts which enter into the constitution of the enamel and of the ivory, by the agent of new formation.

XVIII. Dental caries, or rather the anatomic predispositions to it, are transmissible by heredity, in the family and in the race, a fact that explains the caries which attacks by preference certain consanguineous groups, or certain populations.

XIX. Dental caries affects in its march a direction represented by an imaginary line extending from the point primitively altered to the centre of the pulp cavity.

XX. Nevertheless this direction is modified in some circumstances, sometimes by the nature of the altering agent, sometimes by the acts of resistance of the tooth itself.

XXI. The symptoms of caries may be divided into three successive periods: —

*First period, caries of the enamel:* habitual indolence or slight sensations when *excited.*

*Second period, middle caries:* pain when *excited* ordinary and constant; *spontaneous* pain rare.

*Third period, penetrating caries: spontaneous* pains under the form of *crises*, together with habitual pain when *excited.*

XXII. Caries is susceptible of spontaneous cure by arrest or suspension in its progress, and the passage of the alteration to the state of *dry caries.*

XXIII. Dental caries is radically curable artificially in the immense majority of cases.

XXIV. The preventive means, prophylaxis of caries, not being able to exert any well marked influence on the anatomy of the teeth, should have for its aim the suppression of contact with the agents of alteration, or the neutralization of their effects.

XXV. The general mode of curative treatment consists in *isolation*, preceded by the therapeutic treatment appropriate to the symptoms.

XXVI. The *therapeutics* of caries vary according to its period.

In the first period all treatment is useless, and the operation, resection or obturation, is at once possible.

In the second period, the employment of astringents and superficial caustics.

In the third period, application of profound caustics and destruction of the pulp.

XXVII. *Isolation* of caries is represented in practice by two operations: —

1. Resection for some superficial cases.
2. Obturation for all of any depth.

XXVIII. The term of possibility of the cure of caries is marked by the development of grave lesions of the alveolo-dental periosteum, occasioning local disorders or general disturbances necessitating the extraction of the tooth.

# EXPLANATION OF THE PLATES.

## ANATOMIC LESIONS OF DENTAL CARIES.

---

### PLATE I.

FIG. 1. Vertical section of a lower second molar from a person twenty-five years old. Magnified five diameters.

*a*, *a*. Enamel.

*b*. Ivory.

*c*. Cavity of pulp.

*d*, *d*, *d*. Congenital fissures in the enamel in which caries has begun.

*e*, *e*, *e*. First sketch of the white zone, or cone of resistance, produced by obliteration of the canalicules.

FIG. 2. Vertical section of a lower first molar from a person twenty years old. Magnified five diameters.

*a*. Enamel.

*b*. Ivory.

*c*. Pulp cavity.

*d*. Furrow in the enamel where caries has begun.

*e*. Beginning of the invasion of the ivory by caries, surrounded by an isolating line.

FIG. 3. Vertical section of the crown of a first adult molar. Magnified five diameters.

*a*. Enamel.

*b*. Ivory.

*c*. Cavity of the pulp.

*d*. Nearly cylindrical caries of the enamel, with a minute persistent ridge in the centre.

*e*. Resistant cone not quite arrived at the pulp cavity.

FIG. 4. Vertical section of the crown of an upper second molar from a person of about twenty years. Magnified five diameters.

*a*. Enamel.
*b*. Ivory.
*c*. Cavity of the pulp.
*d*. Vast hollow in the triturant face.
*e*. Cone of resistance reaching the cavity of the pulp over a considerable surface, but without presenting any other appearance of secondary dentine.

FIG. 5. Vertical section of an upper first molar. Magnified five diameters.

*a*. Enamel.
*b*. Ivory.
*b'*. Abundant layers of globular dentine.
*c*. Cavity of the pulp.
*d*. Superficial caries of the enamel.
*e*. Cone of resistance not yet reaching the external surface, but reaching the pulp cavity.

FIG. 6. Vertical section of the crown of an upper adult bicuspid. Magnified five diameters.

*a*. Enamel.
*b*. Ivory.
*c*. Cavity of the pulp.
*d*. Lateral cavity that has entirely destroyed the enamel layer and invaded the cone of resistance. The tip of this cone at the pulp cavity presents at *e* a rounded prominence formed of secondary dentine, with proportionate retreat of the pulp.

FIG. 7. Vertical section of the crown of an upper bicuspid. Magnified five diameters.

*a*. Enamel.
*b*. Ivory.
*c*. Cavity of the pulp.
*d*. Lateral caries which has invaded the ivory and reached the cone of resistance.
*e*. Minute portion of secondary dentine formed by the pulp and projecting into its cavity.
*f*. Caries of the enamel beginning on the opposite side and already causing a trace of a cone of resistance.

## PLATE II.

FIG. 1. Vertical section of the crown of an upper bicuspid. Magnified five diameters.

*a*. Enamel.

*b*. Ivory.

*c*. Cavity of the pulp considerably reduced in extent.

*d, d*. Two caries at two laterally opposite sides of the crown, causing in the ivory two whitish opposite cones, pointing at their tips to a bit of secondary dentine occupying almost the whole diameter of the pulp cavity.

FIG. 2. Vertical section of the crown of a lower bicuspid from a person of about forty years. Magnified five diameters.

*a*. Enamel.

*b*. Ivory whose free portion is worn away.

*c*. Cavity of the pulp.

*d*. Immense penetrating caries invading the centre of the tooth, which presents at *e* a wall in the form of a kind of band of secondary dentine occupying the bottom of the cavity and projecting into the dental canal, which is entirely obliterated.

FIG. 3. Vertical section of the crown of an adult upper canine. Magnified five diameters.

*a*. Enamel.

*b*. Ivory.

*c*. Immense cavity developed on the summit of the tooth and penetrating to its centre.

*d*. Central cavity completely obliterated by a formation of secondary dentine which is prolonged into the dental canal.

FIG. 4. A. Lower first adult molar, carious and broken through its centre by an accident in preparation, so as to show a nodule of secondary dentine adhering by one side to the cavity containing it, and free otherwheres.

B. The same preparation seen in profile. Natural size.

FIG. 5. Vertical section of the crown of a lower first molar, affected by congenital erosion. Magnified five diameters.

*a*. Enamel broken and eroded over the whole surface of

the crown, corresponding to the transversely furrowed aspect characterizing this anomaly to the naked eye.

*b*. Ivory presenting at *c*, *c′*, *c″* three superposed layers of globular dentine and inter-globular spaces, corresponding to a similar number of transverse furrows in the enamel.

*c*. Cavity of the pulp.

FIG. 6. Vertical section of the preceding shown as magnified two hundred diameters.

*a*. Enamel.

*b*. Ivory with its parallel canalicules.

*c*. First layer of globules of dentine and very abundant inter-globular spaces.

*c′*. Second layer of the same globules less abundant.

*c″*. Third layer, the most interior of these appearances, beyond which the preparation shows perfectly normal ivory as far as the wall of the pulp cavity.

FIG. 7. Vertical section of the crown of a lower first molar affected by erosion. Magnified five diameters.

*a*. Enamel filled with congenital furrows and pits.

*b*. Ivory showing several superposed layers of globular dentine.

*c*. Cavity of the pulp.

*d*, *d*. Lateral caries, destroying the whole enamel, and causing the formation of two cones of resistance reaching the pulp cavity, which shows no signs of secondary dentine.

FIG. 8. Contents of carious cavity. Magnified five hundred diameters.

*a*, *a*, *a*. Débris of carious ivory.

*b*, *b*, *b*. Débris of dissociated enamel prisms.

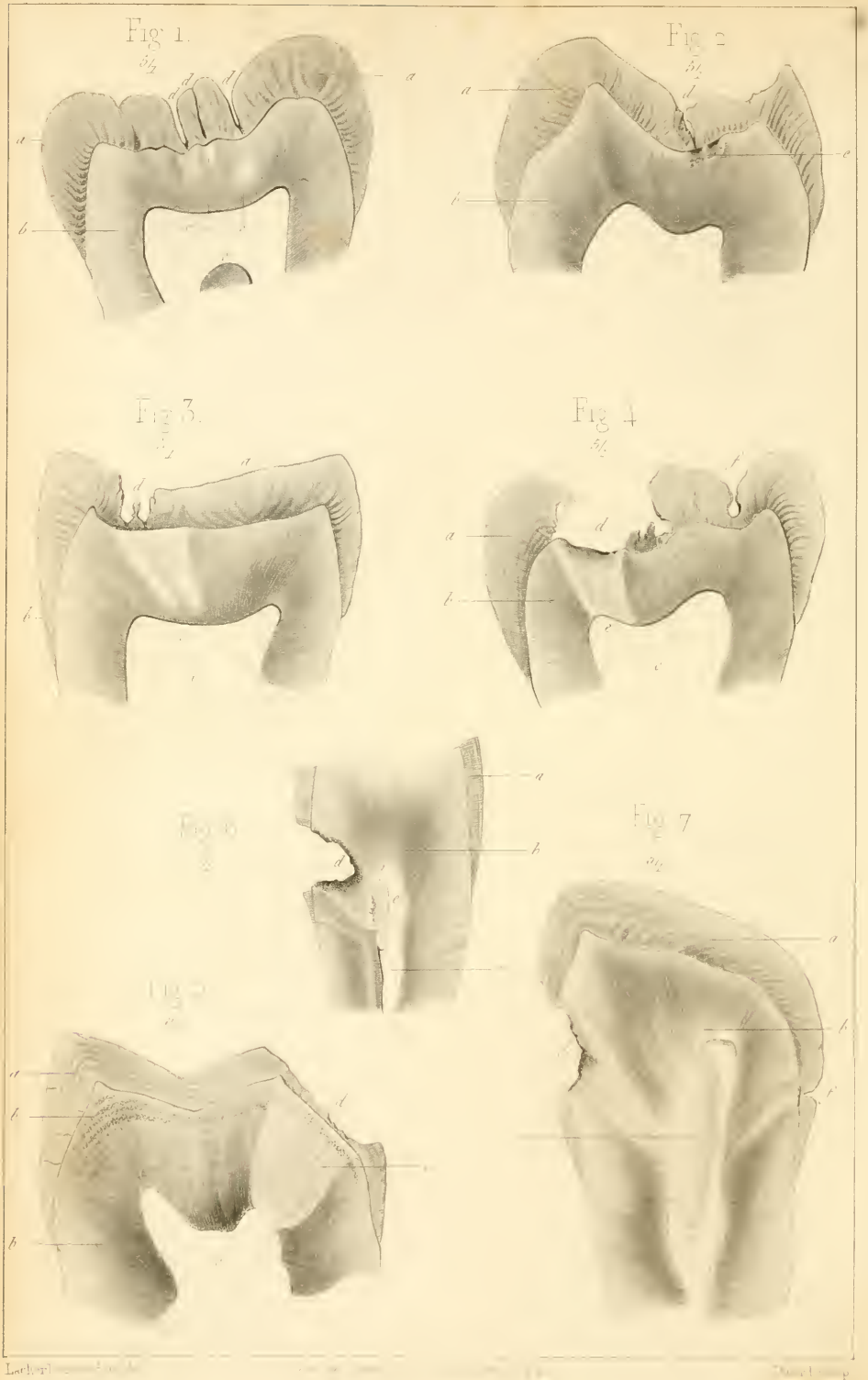
*c*. Pavement epithelial cells of the mucous membrane of the mouth.

*d*, *d*, *d*. Leucocytes.

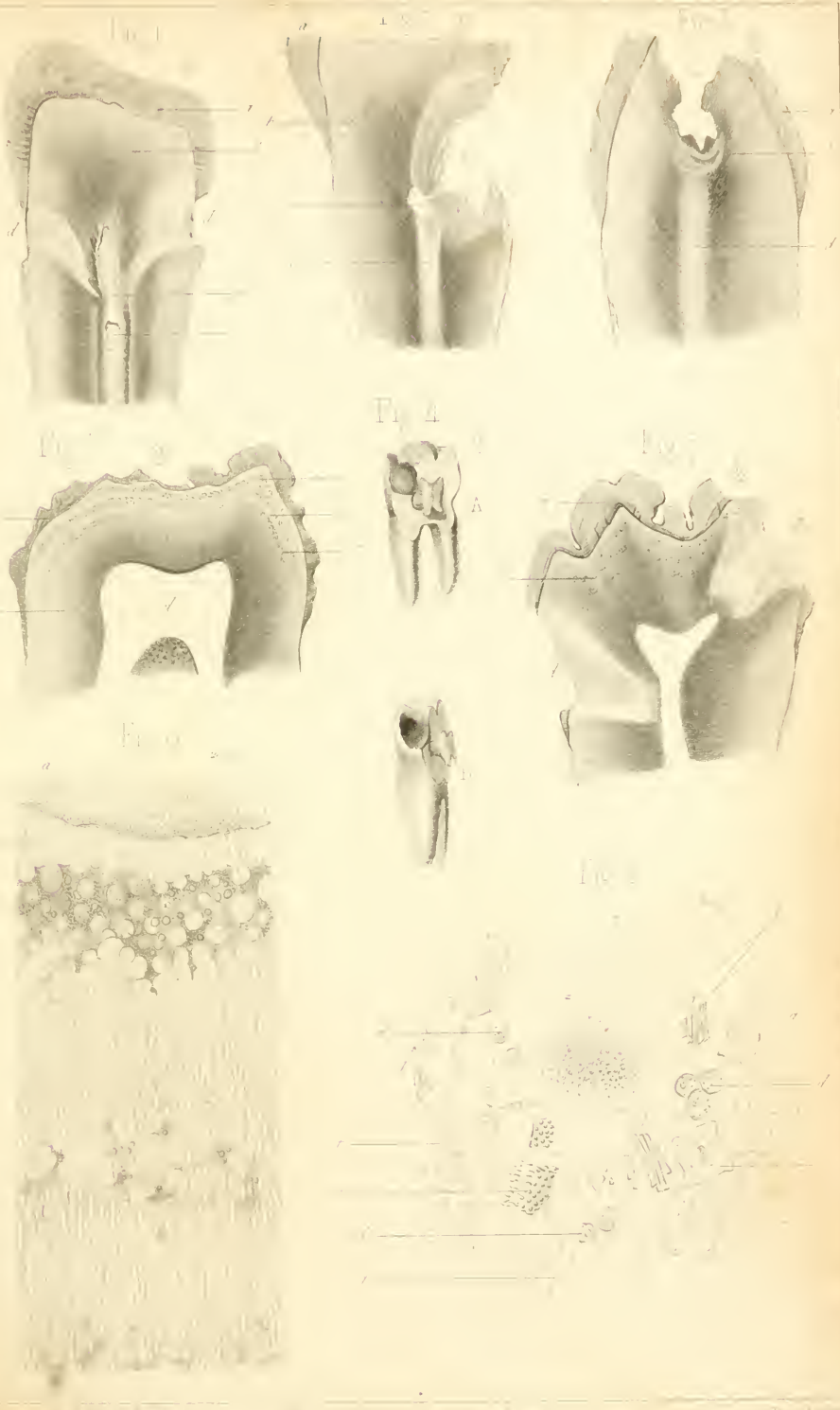
*e*. Mass of filiform algæ of the mouth.

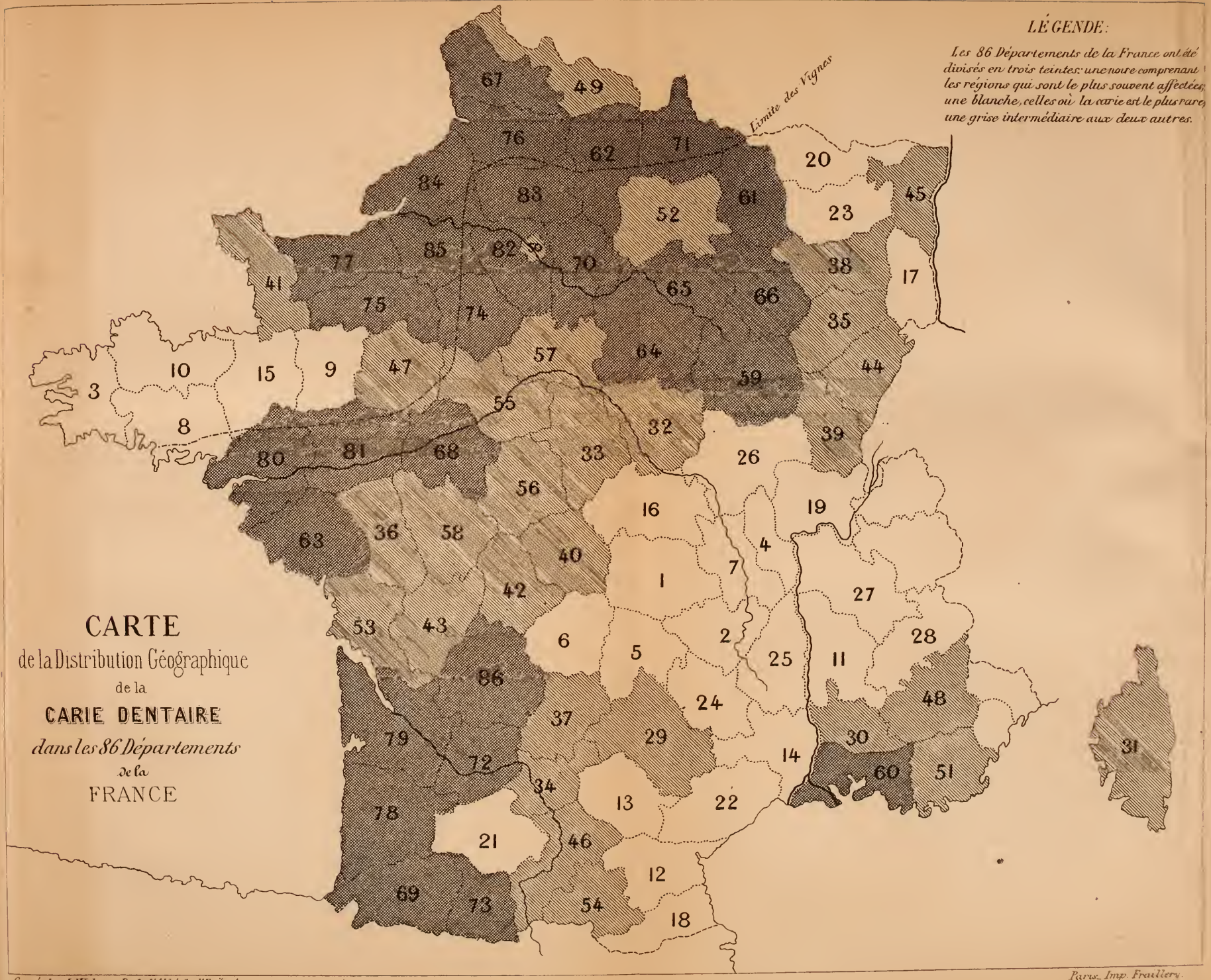
*f*. Oïdium resembling that of thrush.

*g*. Vibrios (*vibrio lineola*).




LESIONS ANATOMIQUES DE L'IVOIRE ET DE L'EMAIL






Gravé chez L. Wuhrer, R. de l'Abbé de l'Epée, 4.

Paris. Imp. Fraillery.

# INDEX.


Abbeville, 5.
Abscess, fistula from, 250.
Accessory parotid, 88.
Acidity of contents of carious cavity, 41.
Acid, acetic, 149; butyric, 137; carbonic, 143; citric, experiments with, 138–140; malic, 141; medicines, 114; propionic, 138; reaction of fermentation products, 106; valeric, 138; viands, abuse of, 210.
Acids, volatile, in mouth, 106.
Acute diseases as causes of caries, 115.
Albumen, experiments with, 145; in saliva, 93; of pulp, 25.
Albuminoids, 145.
Alkaline carbonates, 99; chlorides, 103; lotions, 208; salivas, 111.
Alimentation influencing caries, 113.
Alum a cause of caries, 114; experiments with, 147; in tooth powders, 211.
Alveolo-dental periosteum, description of, 26.
Amalgam, formula of, 246.
Anastomotic plexus, 14.
Anatomic conditions, acquired, 83; lesions, division of, 28.
Anatomy, pathologic, 11.
Anthropomorph apes, caries in teeth of, 5.
Ancient plugging of teeth, 7.
Animalcules in carious cavity, 43.
Arabs and other races, teeth of, 72.
Arrest of caries, 33, 44.
Arsenic, destruction of pulp by, 233; complications with, 240; time of application to pulp, 239; use of, 213.
Artificial caries, 50.
Astringents, use of, 214.
Atrophied teeth, 59.

Bell, theory of, 8.
Bernard, Claude, 86.
Berzelius, 87.
Bibra, 101.
Bidder and Schmidt, 88.
Boucher de Perthes, theory of, 5.
Boudet, 90.
Brown, Dr., experiments of, 156.
Butyric acid, experiments with, 137.
Butyric fermentation, 107.

Canals, course of, 14, 23; calibre of, 15, 40; fluid in, 16; obliterated in carious dentine, 38; sinuous, in secondary dentine, 40; walls of, 16.
Capsule, persistent, 19.
Caries a chemical lesion, 9, 164; among the ancients, 73; as affected by locality and diet, 71; as affected by pregnancy, 82; affected by race, constitution, and diathesis, 70, 81; age of greatest fre-

quency, 60; arrest of, 2, 33, 44; artificially produced, 4–9; at the necks of teeth, 36, 70; caused by saliva, 2; caused by sugar, 134; complications of, 185; contagion of, 163; cured by cauterization, 6; definition of, 2; denuding, 174; dry, 44, 176; distinction between that of living and dead teeth, 127; empiricism in study of, 4; external and internal, 9, 17; exemption from military service caused by, 74; first period, 167; second period, 34, 37, 173; third period, 178; favorite places of, 69; hereditary, 70; history of, 4; in domestic animals, 5, 209; in fossil jaws, 5; isolation of, 244; mechanical cure of, 9; mechanism of, 50, 158; modern opinions of its nature, 8; no analogy between dental and osseous, 2; not caused by inflammation of tooth substance, 8; odor of, 43; of enamel, description of, 29; penetrating or deep, 45; progress of, 167; resembling wear, 37; serpiginous, 36; superficial, 28; time of origin of, 58; two kinds of, 9.
Carious cavity, contents of, 41.
Caustics, use of, 213.
Cauterization of teeth, 6.
Cavities in dentine, 16.
Cavity of caries, communication with pulp cavity, 46.
Cavity, form of, of caries of second period, 35; pulp, shape of, 12.
Calculi in pulp, 48.
Capillary action, 112.
Carbonic acid, 143.
Carbonic acid gas, from parotid saliva, 86.
Care of teeth in sickness, 118.
Cascine in saliva, 93.
Cells, epithelial, in saliva, 93; found in carious cavity, 43.
Celsus, 6.
Cement, action of acetic acid on, 151; development of, 21; hydraulic, for plugging teeth, 247; position of, 11.
Chemical constituents of parotid saliva, 87.
Chemical nature of erosion, supposed, 56.
Chlorides in saliva, 103.
Chronic disease affecting the saliva, 119.
Cicero, 6.
Cider, experiments with, 141.
Citric acid, 138–140.
Cœlius Aurelianus, 6.
Color of caries of enamel, 30; change of, after luxation, 85; of dead tooth, 244.
Comparative decay, table showing, 59.
Conclusions, twenty-eight, 264–268.
Congenital conditions, 50.
Congenital imperfections, two kinds of, 51.
Cone of resistance, 32.
Constitution as affecting caries, 70, 81; evidenced by teeth, 51.
Contact, effect of, 164.
Contour, lines of, 13.
Corpuscles, osseous, 22.
Cracks in teeth causing caries, 83.
Curative treatment, 211.
Curves showing frequency of caries in different teeth, 61–67.
Cuticle, enamel, 19, 30.
Cuvier, membrane of, 14; theory of, 8.
Cysts, teeth in ovarian, 168.
Czermak, 17.

Damocrates, 6.
Deciduous teeth, relative frequency of decay in, 68.
Defects, internal, 51.
Density of ivory increased, 170.
Dental pulp, description of, 24.

Dentification, complete, of pulp, 40.
Deutifrice, formula, 208.
Dentifrices and lotions, acid, 211.
Dentine, action of acetic acid on, 151; carious, appearance of, 37; carious, granulations found in canals of, 42; carious, obliterated canals in, 38; cavities in, 16; globular spaces in accompanying erosion, 56; description of, 11–15; increased density of, 170; secondary, 33, 47, 179; secondary in pulp cavity, 39; secondary, size of canals in, 40; sensibility in, 17.
Dentistry in middle ages, 7.
Dentition, time of beginning of first, 82.
Diagnosis, 193.
Diathesis as affecting caries, 70, 81.
Diet as affecting caries, 72.
Dioeles, 6.
Disappearance of pulp, 45, 48, 251.
Diseases affecting the saliva, 115.
Disturbances of tooth germ before eruption, 51.
Domestic animals, caries of teeth in, 5.
Donné, discoverer of acid saliva in sickness, 118.
Drainage of pulp cavity, 249.
Drinks causing caries, 78.
Dry caries, 44, 176.
Duval, description of caries, 190; theory of, 8, 37.

Edge, setting on, 112.
Empiricism in the study of caries, 4.
Enamel, covered partly by the cement, 11; of caries of second period, 38; color of caries of, 30; cuticle, office of, 30; cuticle, 19; description of, 19; lacunæ in, 20; layer, imperfections in, 52; position of, 11; prisms, 19; prisms found in carious cavity, 42; organic change in, 21.
Epithelial cells in saliva, 93.
Erasistratos, 6.
Erosion, simultaneous, in homologous teeth, 57; supposed chemical nature of, 56; teeth affected by, 53.
Esculapius, 6.
Etiology, chap. ii., 50.
Evolution, follicular, 55; intramaxillary, 58.
Exemptions from service from other causes than caries, 80.
Exostoses, 22.
Experiments in the mouth, 121; laboratory, 127; with the sugars, conclusions, 130–133; with lactic acid, 135–137; with butyric acid, 137; résumé of, 155.
Extraction, preventive, 206; a cause of neuralgia, 201.

Fatty matters in saliva, 94.
Fauchard, opinions of, 8.
Faults of conformation, 50.
Fermentation, conditions of, 105; rapidity of, 109; in saliva, 91, 104; of sugars, 133; products, acid reaction of, 106.
Fistula from abscess, 250.
Follicular evolution, 55.
Forceps of lead of Esculapius, 6.
Form of tooth at its eruption, 50; of teeth, hereditary, 51, 71.
Fox, theory of, 8.
Fractures of teeth causing caries, 83.
France, departments of, table of comparative exemptions, 75.
Fuliginous concretions, 116.
Fundamental substance, 12.
Fungous gum, 48; pulp, 48, 186.

Galen, 6.
Gangrene of tooth substance, 8; of pulp, 46.
Gerdy, 33.

Germ, disturbances of before eruption, 51.
Giraldès, mucous cysts, etc., 188.
Glands, muciparous, 88; tartaric, 101.
Globular spaces in dentine accompanying erosion, 56.
Globules, dentinal, 13.
Granular layer, 14.
Granulations found in canals of carious dentine, 42.
Grease, globules of, in carious cavity, 43.
Grooves in masticating surface of molars, 51.
Gum, fungus of, 48.

Hannover, 16, *et passim.*
Harris, 9.
Haversian canals in teeth, 22.
Health of mother as affecting teeth of first dentition, 82.
Henle, 31.
Heraclides, 6.
Hereditary beauty of teeth, 51; predisposition to caries, 70, 80.
Herophiles, 6.
Hexagonal depressions in dentine, 12.
Hippocrates, books of, on caries, 6.
Hunter, theory of, 8, 168.
Huxley, 12.
Hypertrophy of pulp, 48.

Inflammation of pulp, 46, 181; of tooth substance, 8.
Infusoria in carious cavity, 43.
Inorganic substances in saliva, 99.
Interglobular spaces, 13.
Internal caries, 9, 17; non-existent, 168, 192.
Iron, preparations of, injurious, 156.
Isolation of caries, 212, 244.
Ivory, description of, 11–13.

Jourdain, opinions of, 8.

Kölliker, enamel cuticle, 19; description of dentinal canals, 15.

Lactates in saliva, 103.
Lactic fermentation, 106.
Lacunæ in enamel, 20.
Lassaigne, experiments of, 154.
Lead forceps of third Esculapius, 6.
Leeuwenhoeck discovers canals, 14.
Lehman, 87.
Leptothrix buccalis, 43, 98.
Leucocytes, found in carious cavity, 43; in saliva, 93.
Linderer, theory of, 8.
Locality as affecting caries, 72.
Loss of teeth, spontaneous, 40.
Luxations of teeth, 85.

Malic acid, experiments with, 141.
Mantegazza, experiments of, 135.
Mechanism of production of caries, 50.
Meckel, theory of, 8.
Medicines, acid, cause caries, 114.
Membrana intermedia, 24.
Membrane of Cuvier, 14.
Microscope, investigations by, 7.
Middle ages, dentistry in, 7.
Mitscherlich, 86.
Mixed saliva, 89.
Molars, grooves in crown surfaces of, 51.
Monad, 101.
Morbid changes of saliva, 115.
Mouth-wash, formula, 207.
Muciparous glands, 88, 96.
Mucosine, 96.
Mucus, globules of, in carious cavity, 43.
Mucus, 89–94.
Müller, J., opinion of, 14.

Nasmyth, opinion of, 13, *et passim.*
Nature of caries, 8.
Neck of tooth, caries of, 37, 70.

Necrosis of tooth substance, 8.
Neuralgia from caries, 185; dental, 200; from extraction, 201.
Nodules of dentine in pulp cavity, 40.
Nosology and diagnosis, 190.
Nursing as a cause of caries in nurse, 121.
Nutrition of pulpless tooth, 243.

Obliteration of canal, 47.
Obturation, 205–212; materials used in, 244; method of, 216; temporary, 247.
Odontalgia, description of, 199.
Odor of caries, 43; of mouth, 106.
Oïdium in carious cavity, 43, 98.
Organic matters in saliva, 93, 96.
Orifice of communication between the cavity of caries and pulp cavity, 46.
Osseous corpuscles, 22.
Osteoplasts, 22; direction and size of canals of, 23; union of with dentinal canals, 24.
Oudet, 9, *et passim.*
Ovarian cysts, teeth in, 168.
Owen, 12, 32.
Oxychloride of zinc, 246.

Parasites, in saliva, 98; vegetable, action of in caries, 43.
Paré, Ambroise, regards teeth as bones, 87.
Parotid gland, 87; saliva, 86.
Pasteur, theory of, 164.
Pathologic anatomy, 11.
Pavement epithelial cells found in carious cavity, 43.
Penetrating caries, 45.
Period of caries: first, 167; second, 173; third, 178.
Periosteum, dental, description of, 26; intolerance of, 250.
Periostitis, alveolo-dental, 242.
Persistent capsule, 19.
Phosphates in saliva, 100.
Place of choice of caries, 69.
Plates, explanation of, 265.
Plexus, anastomotic, 14.
Plugging, 244; materials used in, 244; teeth, 205; of teeth by the ancients, 7.
Plugs, formula for temporary, 247.
Polished grooves at neck, 37.
Polypi of pulp and gum, 48.
Potassa, tartrate of, 152; bi-oxalate of, experiment with, 148.
Potassium, sulpho-cyanide of, in saliva, 104.
Predisposing conditions, 50.
Pregnancy, causing caries in mother, 120; causing caries in child, 82.
Prehistoric teeth, caries less frequent in, 5.
Prisms, enamel, arrangement of, 19; enamel, found in carious cavity, 42.
Products of fermentation, 106.
Progress of caries, 167.
Propionic acid, 138.
Ptyaline, 87, 97.
Pulp canals, obliteration of, 47.
Pulp cavity, configuration of, 12; drainage of, 249; secondary dentine in, 39; size in aged, and in the infant, 12.
Pulp, chemical constituents of, 25; description of, 24; destruction of, 183; diminishes with age, 25; disappearance of, 39, 45, 48, 251; embryo-plastic cells in, 26; intolerance of, 249; inflammation of, 181; hypertrophy of, 48; gangrene of, 46, 48; fungous, 48, 186; putridity of, 46, 47; strangulation of, 182.
Pulpless tooth, nutrition of, 243.
Purkinje, 22.
Putrefaction, 105.

Race as affecting caries, 70, 80.

Rapidity of eruption as affecting caries, 82.
Raschkow, opinion of, 13.
Reaction of mixed saliva, 91.
Regnart, experiments of, 156, *et passim.*
Resection of caries, 212, 214.
Résumé of data of frequency of caries, 68.
Retzius, opinion of, 14.
Rivers, course of as influencing caries, 78.
Robin, 22.
Rodents, constant growth of teeth in, 12.
Rôle of saliva in caries, 50.

Salivas, alkaline, acid, and neutral, 89–111.
Saliva, normal, 86; experiments in, 122; effects of upon plates of ivory, etc., worn in the mouth, 122; and its modifications, 85–105; of teeth and gums acid, 90; odor of, 91; physiological action of, 92; rôle of, in caries, 50.
Salivation from caries, 187.
Salt, action of, 153.
Scribonius Largus, 6.
Sea, neighborhood of, as influencing caries, 78.
Second period of caries, 34.
Secondary dentine, 179; size of canals in, 40; formation of, 33; in pulp cavity, 39.
Selzer water, 144.
Sensitive dentine, treatment of, 219.
Separation of dentine by hydrochloric acid, 13.
Serpiginous caries, 36.
Serres, M., opinions of, 101.
Setting on edge, 112.
Sickness, care of teeth in, 118; causing caries, 81.
Simultaneous erosion in homologous teeth, 57.
Soft parts of teeth, 24.
Sorel, paste of M., 246.
Spaces, interglobular, 13.
Spicules of secondary dentine in pulp, 48.
Sprengel, 7.
Stains on the teeth, 98.
Strabo, 6.
Strangulation of pulp, 182.
Strasburg, school of, in 1548, mentioned, 7.
Stratum intermedium, 24.
Structure of the tooth, 11.
Sublingual saliva, 88.
Submaxillary saliva, 88.
Substances that ferment, 106.
Sugar, abuse of, 210.
Sugars, fermentation of, 133.
Sulphates in saliva, 103.
Symptomatology of caries, 167.

Table, comparative tendency to caries, 59; of exemptions from military service in France, 75; frequency of caries in temporary teeth, 68.
Tannin, experiments with, 154.
Tarentum, school of, 6.
Tartar, formation of, 100; from disuse of teeth, 251; signification of, 103.
Tartaric glands, 101.
Tartrate of potassa, action of, 152.
Teeth of Arabs and other races, 72; atrophied, 59; disuse of, a cause of tartar, 251; forms of, hereditary, 71; hard portions of, 11.
Temperaments as affecting caries, 81.
Temporary plugs, formula for, 248.
Tendency to caries, comparative table, 59.
Texture of teeth determined by microscope, 7.
Time of production of caries, 58.
Tomes, 21, *et passim.*

Tooth, human, constant growth of, 12; form and volume of, at eruption, 50; neck, caries of, 37; special character of, 3.
Traumatism a cause of toothache, 248.
Treatment, 204; curative, 211; of first period, 213; of second period, 218; of third period, 227; therapeutic, 213.
Tumors, of pulp, 48; of tongue and cheek from caries, 187.

Union of cavity of decay with pulp cavity, 49.

Valerie acid, 138.
Vauquelin, 101.
Vegetable parasites in carious cavity, 43.
Vibrio-lineola in carious cavity, 43, 98.
Vices of conformation, 50.
Viscous saliva, 90.
Volume of tooth at its eruption, 50.

Water in saliva, 92.
Wear of teeth, influence of, 84; of teeth by clasps, etc., 85.

Zone of resistance, 32.